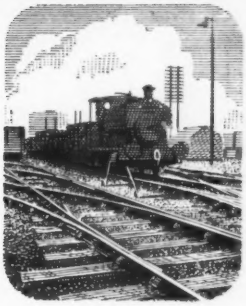
Railway Traffic of the Appleby-Frodingham Steelworks



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SYNOPSIS

The works site and distribution of plant are reviewed in relation to material supplies and external communications. An analysis of the inward, outward, and internal railway traffic, amounting to 268,750 net loaded tons per week, is given, with consideration of other handling methods. The layout of 100 miles of internal railway is illustrated, with reference to the principles adopted. Works rolling stock, which includes effectively 1841 wagons and 55 locomotives, is described, with an analysis of circulation and performance. The terminal time for inward and outward traffic is shown to be about 1·5 days, and methods of unloading surplus material are outlined, together with those for waste material. Systems used for the recording and organization of internal traffic are described, and are related to the general needs of works production. 697

THIS general account of railway traffic at the Appleby-Frodingham iron and steel works of The United Steel Companies, Ltd., at Scunthorpe, may usefully supplement investigations now proceeding into special features of traffic operation within the iron and steel industry.

WORKS SITE AND DEVELOPMENT

The origin of the works was at the outcrop of the local Frodingham ore bed, at about 100 ft. datum. This bed has an eastward dip under a lesser surface dip; it is now worked at about zero datum, mainly opencast, but with underground methods increasing. Works development has followed eastward on ground refilled in level terraces, each with level connection to a British Railways route that follows the local surface dip on its way from Doncaster, *via* Stainforth, Scunthorpe, and Barnetby to Immingham and Grimsby. The British Railways facilities at Scunthorpe include ' West ' and ' East ' marshalling yards with direct connections to Appleby-Frodingham, a direct connection to the neighbouring Redbourn (Richard Thomas and Baldwins) works, and a branch to the Normanby Park (Lysaghts) works. The ' West ' yard, with sidings for 1900 wagons, handles works inward loads and empties, plus outward empties. The ' East ' yard, with sidings for 1500 wagons, handles works outward loads.

Although all parts of the works are interconnected, they are most conveniently described under area headings. Figure 1 shows the general disposition of plant, including the five main-line connections known as Entrances *A–E*. References are given to Fig. 1.

Frodingham Works (*Entrance* A)—Ironworks started in 1868. Now two blast-furnaces (15) on 100-ft. datum, with materials gantries rising to 139 ft. Steelworks added nearby in 1890. Melting shop replaced (*see* below). Heavy section mill recently rebuilt on original site (24). Structural shops (26) recently extended.

Appleby Steelworks (*Entrance* B)—Started in 1927 on 80–82-ft. datum. Appleby Melting Shop (20) and plate mills (23) both since enlarged. Pig-casting machine (19) added in 1939. New Frodingham Melting Shop (21) added in Appleby area in 1947, on 81-ft. datum.

North Ironworks (*Entrance* C)—Started independently in 1877 and bought in 1912. Now four blast-furnaces (16) on 66-ft. datum, with materials gantries rising to 108 ft.; also early sinter plant (17).

Coke Ovens and South Ironworks (*Entrances* D *and* E)—Ovens (9), started in 1939 with coal unloading and preparation plant (8) on 77-ft. datum, and chemical plant (10); output recently doubled. South ironworks started in 1939 with two blast-furnaces (14) on 74-ft. datum; also central ore unloading and preparation plant (11) on 80-ft. datum, to serve all three ironworks, with prepared ore storage (12) and wagon-loading station (13) for material to Frodingham and North. Two new furnaces and duplicate ore-preparation plant now under construction.

British Railways deliver loads and empties into the works at Entrances *A–E*. They also collect from *A*, *C*, and *E*; works haulage delivers into the railway yards from *B* and *D*. At the complementary Entrances *D* and *E*, minor traffic uses the former and major traffic the latter.

ARRIVAL OF WORKS MATERIALS

The local limy Frodingham ore of 20–22% iron content forms three-fifths of the ironworks raw material, and is delivered by private haulage of the associated Ore-Mining Branch to sidings (6 and 7, Fig. 1) at the works boundaries. This ore contains mud and boulders, and cannot be rehandled for storage in the raw condition. With direct loading from daytime excavation, and gradual unloading to continuous preparation processes, the works wagons

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1. Railway entrance *A* (Frodingham Works)
2. Railway entrance *B* (Appleby Steelworks)
3. Railway entrance *C* (North Ironworks)
4. Railway entrance *D* (Ovens and South Ironworks)
5. Railway entrance *E* (Ovens and South Ironworks)
6. Local ore reception (North Boundary Sidings)
7. Local ore reception (South Boundary Sidings)
8. Coke-oven coal plant
9. Coke-oven batteries
10. Coke-oven chemicals
11. Ironworks ore preparation
12. Prepared material storage
13. Prepared material loading
14. South blast-furnaces
15. Frodingham blast-furnaces
16. North blast-furnaces
17. North sinter plant
18. Ironworks slag plant
19. Pig-casting plant
20. Appleby Melting Shop
21. Frodingham Melting Shop
22. Steelworks slag plant
23. Appleby Plate Mills
24. Frodingham Heavy-Section Mill
25. Frodingham Light-Section Mill
26. Constructional shops
27. Central Engineering Shops
28. Appleby loco. shed
29. Frodingham loco. shed
30. Wagon repair shops
31. Central Traffic Office
32. General stockground (South)
33. General stockground (North)
34. Ironworks slag banks
35. Steelworks slag banks, connected by tramway (not shown) to 22

Fig. 1—Diagrammatic plan of Appleby-Frodingham works and railways, 1951

used have to provide intermediate storage, which restricts their circulation to one local journey per weekday. Tippler unloading has been used since 1939, because it gives the best angle of discharge for difficult material and avoids the use of very special and expensive wagons for limited circulation. The wagons now used are of the common 21-ton type, but additions under construction will be of a 31-ton type with 700 cu. ft. volume, no doors, 20½ ft. overall length, four wheels on 10-ft. wheelbase, 10-in. × 5½-in. bearings, and 9 tons tare. This large non-bogie size will offer low capital and maintenance cost, combined with favourable tare and length/load ratios.

The remainder of the ironworks raw material is siliceous Northampton ore of 30–33% iron content, from the Grantham and Melton Mowbray areas. The British Railways wagons arriving are increasingly of the new 27-ton doorless type with 19¼ ft. overall length, four wheels on 9-ft. wheelbase, and 7¾ tons tare.

Coal for the coke ovens and bought coke for the Frodingham and North ironworks come mainly from South Yorkshire. The coal is unloaded by tippler from a variety of British Railways 12–20-ton wagons. The coke is unloaded at a separate gantry for each blast-furnace. Flat-bottom coke wagons cause serious delay, and the most suitable arrivals are the British Railways 20-ton hoppers, originally introduced by Appleby-Frodingham as private owners. These wagons have 1380 cu. ft. volume, 28 ft. overall length, 11 ft. height, four wheels on 12-ft. wheelbase, and 11¼ tons tare. The projected British Railways 24½-ton mineral wagons with 1029 cu. ft. volume will be welcomed in coal traffic and in supplementary use for coke.

The melting shops on high hot-metal charges use no bought scrap, but receive substantial supplies of limestone, lime, foreign ore, and scale, mainly in ordinary 12–16-ton mineral wagons unloaded by hand or magnet to trays of charger boxes alongside. Limestone arrives in a daily train from near Barnetby, and foreign ore arrives from Immingham. Problems of accepting large cargoes for moderate consumption have been reduced by sharing more frequent cargoes with other steelworks at Scunthorpe or Sheffield.

Other inward loads include lesser steelworks materials, refractories, stores and engineering supplies, and locomotive fuel.

DEPARTURE OF WORKS PRODUCTS

The main works output of steel plates and sections departs westward *via* Stainforth, or eastward *via* Barnetby.

The reloading of empty mineral wagons with steel products is subject to restrictions, and fast-end empties have to be ordered into the works. Bogie wagons are required for the longest loads, but the new 22-ton plate or double-bolster types, with four wheels on 15-ft. wheelbase, 30 ft. overall length, and 9½ tons tare, now cater economically for a wide range of normal consignments. They have substantially reduced the use of under-runners, which complicate the shunting of steel-section traffic.

Pig iron is dispatched in re-used mineral wagons, largely in daily through-trains to associated customers in the Sheffield area. Ironworks slag (roadstone, etc.) is dispatched in similar wagons, and steelworks slag (fertilizer) requires a supply of covered vans.

WORKS RAILWAY HAULAGE

Railway haulage within the works arises in three directions—inward, outward, and internal, each with sorting, weighing, and storing as required *en route*. Quantities hauled in the three directions are shown in Table I. The horizontal paragraphs distinguish ' primary ' traffic, predominant at ironworks with rail supplies; ' ordinary ' traffic, typical of most iron and steel works, and resembling the traffic in other heavy industries; and ' hot ' traffic in vehicles, peculiar to iron and steel processes. The quantities given are for weekly makes of 18,000 tons of pig iron and 18,000 tons of ingots, which have both exceeded 20,000 tons since the table was compiled.

Total Net Loads and Ratio of Inward, Outward, and Internal

The weekly net tons hauled include inward 25·3%, outward 8·8%, and internal 65·9%. The high ratio of inward and internal to outward is due, firstly, to the reception by rail of low-grade material, which may show further slow deterioration; secondly, to the internal haulage of prepared material to the older blast-furnaces, now being partly replaced by new furnaces near the preparation processes; thirdly, to the high slag ratio of 24 cwt. per ton of iron; and, fourthly, to the successive haulage of intermediate products, including hot metal and hot ingots. The haulage of ironworks slag in ladles is likely to continue, as cooling around the furnaces, for excavation and removal in easier form, is precluded by the abnormal quantity and hard quality after setting. The haulage of hot metal in ladles and hot ingots on cars is also likely to continue, as these loads arise in large batch quantities, which are unsuitable for continuous conveying, and which require very flexible transfer between multiple furnace or rolling units, all widely separated by their surrounding auxiliary plant. Limitation of internal haulage has been arranged, wherever practicable so far, by the belt conveying of coke from the ovens and of ore through the crushing, screening, blending, drying, and sintering processes, to storage or use in the newer furnaces nearby; and by the extensive use of transfer by overhead crane and roller racks within the steelmaking and finishing processes.

Average Tare and Distance

The weekly net tons and net ton-miles indicate that loads are hauled through an average distance of 1·28 miles. This is probably not exceptional for large iron and steel works, but it may indicate that there is an optimum limit to the wide spacing of plant as an alternative to congestion.

Total Wagon Movements

The weekly total of 33,530 includes 3750 outward empties from mineral traffic and 1560 inward empties of special types. The difference between the 4390 inward loads and 3750 outward empties, or between the 2200 outward loads and 1560 inward empties, represents 640 wagons unloaded and transferred internally as suitable for reloading.

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Table I—APPLEBY-FRODINGHAM WORKS RAILWAY TRAFFIC

Railway Traffic Hauled Within Works*	Net Loads per Week					Wagons per Week							Wagon Tares per Week				Gross per Week
	Net Tons Hauled†			Loaded Miles‡	Net Ton-Miles Hauled	Load per Wagon, tons¶	Inward		Outward		Internal		Tare per Wagon, tons††	Tare Tons Hauled	Tare Miles‡‡	Tare Ton-Miles	Net and Tare Ton-Miles Hauled
	Inward	Outward	Internal				Loaded	Empty	Loaded	Empty	Loaded	Empty					
Primary Traffic																	
Coal (entrance *E* to ovens tippler)	18,500	...	...	1·84	34,040	13·1	1412	...	...	1272**	...	...	7½	10,237	3·27	33,475	67,515
Part coke make (ovens to Frodingham or North	...	...	2480	1·49	3695	19·0	...	...	...	...	131	131	11½	1507	2·61	3932	7627
Chemical products (ovens to entrance *D*)	...	1360	...	1·13	1537	13·0	...	105	105	...	...	...	9	945	2·26	2136	3673
Bought coke (entrance *A* to Frodingham blast-furnaces)	5880	...	...	0·93	5468	14·5	406	...	...	406	...	...	10	4060	1·61	6537	12,005
Bought coke (entrance *C* to North blast-furnaces)	6620	...	...	0·89	5892	14·5	457	...	...	457	...	...	10	4570	1·41	6444	12,336
Local ore (boundaries to South tipplers)	...	...	41,540	1·68	69,787	20·6	...	...	...	...	2016	2016	8½	17,138	3·11	53,298	123,085
Northants ore (entrance *E* to South tipplers)	27,690	...	...	1·21	33,505	22·5	1231	...	...	1231	...	...	9	11,079	2·17	24,041	57,546
Prepared material (South to Frodingham blast-furnaces)	...	...	14,480	1·32	19,114	19·0	...	...	...	...	762	762	9	6858	2·28	15,636	34,750
Prepared material (South to North blast-furnaces)	...	...	17,350	1·72	29,842	19·0	...	...	...	...	913	913	9	8217	3·04	24,980	54,822
Semi-prepared (South to North sinter plant)	...	...	7340	1·68	12,331	19·0	...	...	...	...	386	386	9	3474	2·97	10,318	22,649
Prepared (North sinter plant to North blast-furnaces)	...	...	5000	0·97	4850	15·0	...	...	...	...	333	333	9	2997	1·62	4855	9705
Flue dust and coke dust (to South sinter plant)	...	...	4090	0·85	3476	13·5	...	...	...	...	303	303	8½	2576	1·39	3580	7056
Flue dust and coke dust (to North sinter plant)	...	...	1200	1·09	1308	11·2	...	...	...	...	107	107	8½	910	1·85	1683	2991
	58,690	1360	93,480				3506	105	105	3366	4951	4951					
Sub-Total	153,530				224,845		3611		3471		9902			74,568		190,915	415,760
Ordinary Traffic																	
Scrap (mills and breakers to both melting shops)	...	...	5200	1·52	7904	12·0	...	...	...	...	433	433	15½	6712	2·16	14.497	22,401
Oxides, lime, limestone (entrance *B* to both shops)	5390	...	...	1·12	6037	11·6	465	...	...	85**	...	...	7¼	3371	1·56	5259	11,296
Finishings, refractories, moulds (entrance *B* to both)	660	...	...	1·12	738	11·0	60	...	...	40**	...	...	7¼	435	1·56	679	1417
Pit scrap and moulds (both shops to breakers)	...	...	620	1·01	626	11·1	...	...	...	...	56	56	10½	588	1·39	817	1443
Steel (mills to structural or pit arch shops)	...	...	1520	1·15	1748	19·2	...	...	...	...	79	79	12	948	2·30	2180	3928
„ (Frodingham sections, etc., to entrance *A*)	...	6150	...	1·13	6950	11·1	...	474**	554	...	...	...	9	4986	2·15	10,720	17,670
„ (Appleby plates to entrance *B*)	...	7260	...	0·97	7042	11·0	...	577**	660	...	...	...	9	5940	1·84	10,930	17,972
Pig-caster iron (to cooling and trans-ship.)	...	...	3600	0·44	1584	23·0	...	...	...	...	157	157	12	1884	0·88	1658	3242
Cold iron (to entrance *B*)	...	3600	...	0·93	3348	10·6	...	...**	340	...	...	...	7½	2465	1·27	3131	6479
Cold slag (mixer slag pits to blast-furnaces)	...	...	900	1·71	1539	16·0	...	...	...	...	56	56	24	1344	2·99	4019	5558
„ „ (basic plant to entrance *B*)	...	2160	...	1·16	2506	9·0	...	240	240	...	...	...	7½	1800	2·32	4176	6682
„ „ (ironworks plant to entrance *E*)	...	1160	...	1·33	1543	12·0	...	...**	97	...	...	...	7½	703	1·96	1378	2921
Rubbish (hauled to tips)	...	...	6700	2·65	17,755	11·8	...	...	...	...	568	568	10	5680	3·79	21,527	39,282
Stockground materials (rehaul ex stock)	...	...	3000	0·60	1800	15·0	...	...	...	...	200	200	7½	1450	0·84	1218	3018
Miscellaneous (inward, outward, internal)	2280	920	630	1·36	5208	8·8	259	64**	104	159**	72	72	7½	3154	2·38	7507	12,715
„ (hauled for neighbouring works)	1000	1000	...	1·75	3500	10·0	100	100	100	100	...	...	7½	1450	3·50	5075	8575
	9330	22,250	22,170				884	1455	2095	384	1621	1621					
Sub-Total	53,750				69,828		2339		2479		3242			42,910		94,771	164,599

Table I (*continued*)

APPLEBY-FRODINGHAM WORKS RAILWAY TRAFFIC

Railway Traffic Hauled Within Works*	Net Loads per Week					Wagons per Week							Wagon Tares per Week				Gross per Week
	Net Tons Hauled†			Loaded Miles‡	Net Ton-Miles Hauled	Load per Wagon, tons¶	Inward		Outward		Internal		Tare per Wagon, tons ††	Tare Tons Hauled	Tare Miles‡‡	Tare Ton-Miles	Net and Tare Ton-Miles Hauled
	Inward	Outward	Internal				Loaded	Empty	Loaded	Empty	Loaded	Empty					
Hot Traffic																	
Slag (South blast-furnaces to pits and banks)	...	...	8760	1·04	9110	12·2	...	...	...	...	718	718	31¼	22,438	2·08	46,670	55,780
„ (Frodingham blast-furnaces to pits and banks)	...	...	5040	0·99	4990	11·8	...	...	...	...	427	427	33½	14,305	1·98	28,323	33,313
„ (North blast-furnaces to pits and banks)	...	...	7800	0·72	5616	8·4	...	...	...	...	929	929	20½	19,045	1·44	27,424	33,040
„ (both melting shops to banks)	...	...	3870	0·60	2322	12·7	...	...	...	...	305	305	24	7320	1·20	8784	11,106
Metal (South blast-furnaces to mixers and pig caster)	...	...	7300	0·72	5256	46·0	...	...	...	...	159	159	65	10,335	1·44	14,882	20,138
„ (Frodingham blast-furnaces to mixers and pig caster)	...	...	4200	1·32	5544	46·0	...	...	...	...	91	91	65	5915	2·64	15,616	21,160
„ (North blast-furnaces to mixers and pig caster)	...	...	6500	1·19	7735	46·0	...	...	...	...	141	141	65	9165	2·38	21,813	29,548
Ingots (Appleby shop to Appleby stripper)	...	...	10,680	0·28	2990	17·0	...	...	...	...	628	628	35½	22,451	0·56	12,573	15,563
„ (Appleby shop to Frodingham stripper)	...	...	2320	0·70	1624	14·4	...	...	...	...	161	161	26½	4267	1·40	5973	7597
„ (Frodingham shop to Frodingham stripper)	...	...	5000	0·91	4550	13·7	...	...	...	...	364	364	26½	9646	1·82	17,556	22,106
	Nil	Nil	61,470				Nil	Nil	Nil	Nil	3923	3923					
Sub-Total	61,470				49,737		Nil		Nil		7846			124,887		199,614	249,351
							4390	1560	2200	3750	10,495	10,495					
	68,020	23,610	177,120				5950		5950		20,990						
Grand Total	268,750				344,410		33,530¶¶							242,365		485,300	829,710

* Items exclude separate haulage from local mines to works boundaries, and narrow-gauge haulage from slag banks to slag plants

† Net tons recorded once only until unloaded for use or stock; also excludes wagon tares and weights of slag pans, ingot moulds, or scrap pans and trays

‡ Based on normal routes with reversing clearances for middle wagons of normal trains; includes 220 yd. for weighing (where off normal route) and 440 yd. for one storage movement (except hot slag, metal, and ingots)

¶ Excludes wagon tares and weights of slag pans, ingot moulds, or scrap pans and trays

** Empties balanced by transfers from unloading to reloading

†† Includes weights of slag pans, ingot moulds, or scrap pans and trays

‡‡ Showing wagon distances under load and as empties before or after; total is less than twice the loaded miles if there is no weighing or storage of empties, or short transfer to reloading

¶¶ Includes 640 transfers from unload to reload

WORKS RAILWAYS

The general layout shown in Fig. 1 appears to be triangular, but it is functionally a spoked wheel with inward and outward, or slag and rubbish-bank, connections at the rim and main internal connections through the hub. Railways within the works boundaries are listed in Table II. As their total length is about 100 miles, the mileage items are a percentage allocation.

Sidings Location

A normal distinction is made between reception or departure sidings for wagon standing incidental to shunting programmes, holding sidings for the reserve standing of wagons classified by contents, and sidings in which wagons are set for loading or unloading. The distinction cannot be rigid, however, as it may be necessary to delay heavily bunched arrivals in the reception space, or to vary the contents of holding space. Although some of the inward holding space is near to the unloading positions, the greater part is near reception. This permits the prompt disposal of excess arrivals with minimum use of locomotive time, and the programming of longer hauls to final unloading

Table II
RAILWAY MILEAGE

Classification By Use of Railway Tracks within Appleby-Frodingham Works Boundaries (June, 1951)	Works Railway Areas					
	Local Iron-ore Railway, miles	Entrance *A*, with Frodingham Ironworks, section mills, and workshops, miles	Entrance *B*, with both melting shops, plate mills, and pig caster, miles	Entrance *C*, with North Ironworks, miles	Entrances *D* and *E*, with South Ironworks, central ore preparation and ovens, miles	Total, miles
Inward Sidings*						
Local ore reception	0·68	...	...	...	...	4·48
Reception from British Railways	...	0·94	0·46	0·72	1·68	
Storage near reception:						
Coke	...	0·60	...	0·36	...	6·12
Oven coal	...	...	...	...	0·96	
Northants ore	...	...	...	...	0·86	
Steelworks materials	...	...	0·56	...	...	
Inward empties	...	0·58	0·56	...	...	
Miscellaneous	...	1·24	0·24	...	0·16	
Storage near plant:						
Coke	...	0·08	...	0·34	...	3·42
Oven coal	...	...	...	...	0·54	
Local ore	...	...	...	...	0·86	
Northants ore	...	...	...	...	0·58	
Steelworks materials	...	...	0·78	...	...	
Miscellaneous	...	...	...	0·12	0·12	
Unloading at plant	...	0·50	0·84	0·08	1·02	4·42
„ at stockbanks	...	0·10	...	0·52	1·36	
Sub-total	0·68	4·04	3·44	2·14	8·14	18·44
Outward Sidings*						
Loading at plant	...	1·26	0·88	0·04	0·84	3·02
Outward storage	...	0·84	0·36	0·40	0·96	2·56
Departure to British Railways	...	0·48	0·26	0·52	1·44	3·32
Local ore empties	0·62	...	...	...	...	
Sub-total	0·62	2·58	1·50	0·96	3·24	8·90
Internal Sidings*						
Slag and rubbish tips	...	1·40	0·28	1·76	0·80	4·24
Others	...	4·90	4·24	2·12	4·18	15·44
Sub-total	...	6·30	4·52	3·88	4·98	19·68
***Running Routes**†*	3·52	12·20	10·56	8·44	17·46	52·18
Total	4·82	25·12	20·02	15·42	33·82	99·20

* Sidings shown are clear standing lengths. Internal sidings include those for loading, unloading, and storage of internal traffic, and for maintenance of rolling stock.

† Running routes include approaches to all sidings with turnouts measured both ways, and also loops, shunting ends, and weighbridge routes.

positions according to the more even rate of material consumption. Furthermore, the common location of holding sidings for several materials, with some flexibility of use, reduces the total capacity required.

Direction of Shunting Approach

A common direction of approach to all sidings, used for related traffic movements, is arranged, wherever possible, to avoid the wasteful and obstructive operation of locomotives 'running round' their trains. Hot-metal movements from any of the three ironworks to either melting shop or to the pig-casting plant can, for instance, all be undertaken by a locomotive attached to the same end of the train. The same applies to ingots from either melting shop to either stripping shed and to materials from Entrance *B* to the main stockyard approach at either melting shop. Where there are unrelated groups of traffic movements in the same works area, however, their group approaches are desirably arranged from opposite ends to disperse focal shunting points. This applies to blast-furnace supplies near mill dispatches at Frodingham, melting-shop supplies near mill dispatches at Appleby Steelworks, and other instances.

Single- and Double-Ended Sidings

Reception and departure sidings are usually double-ended, so as to allow works and main-line shunting from opposite ends. Most internal sidings are single-ended, to suit the common direction of approach for related traffic and to simplify shunting precautions. Double-ended sidings are used for the handing-over and intermediate storage of scrap or other transfers between areas shunted from opposite ends, however, and also in a few positions to which long and heavy trains are headed by their locomotives.

Single and Double Running Routes

The main railway areas are interconnected at both ends; routes spreading inwards, for main use from one end or the other, are also joined to give alternative through connections for minor or emergency purposes. These inner routes are predominantly single-track, to give the simplest branch connections to either side, and are found to have running capacity for the number and variety of trains concerned, provided that they are separated by clear train lengths from shunting points on branches. Double track does not offer the advantage of separate up-and-down running, unless double connection with three special pieces of trackwork can be made to every branch, and may be dangerous at works level-crossings if long trains in one direction obscure those approaching from the other. Double or multiple track is found necessary, however, in strategic loops to divide long single lengths, to by-pass weigh-bridges, to avoid conflicting movements on curves without clear view, and particularly to ensure uninterrupted passage for uphill trains on inclines. Along the melting-shop and newer blast-furnace frontages, where there are combined running and shunting movements and many branches, two main tracks are each used in both directions for different purposes.

Bridges and Tunnels

Where plant disposition requires cross-movements of heavy unrelated traffic, their separation by bridge or tunnel may be desirable, particularly if differences of level at source or destination reduce the gradients introduced.

Gradients

Internal traffic is predominantly uphill, as the older plant and finishing processes are supplied by newer plant and primary processes on the newer and lower sites. Newer gradients are 1 in 60–80, but other steeper gradients remain in use.

For gravity sidings at tipplers, gradients that will start poor-running wagons in cold weather or after long standing are excessive for good-running wagons in hot weather or after recent movement. Gradients provided at 1 in 70–80 in 1939 have proved too steep, particularly for wagons leaving tipplers, and preference is now for 1 in 100. This is deliberately rather flat for starting on-going wagons, and still rather steep for checking off-going wagons, as adjustments can then be made experimentally by the simple addition of track ballast to approach humps and receiving hollows.

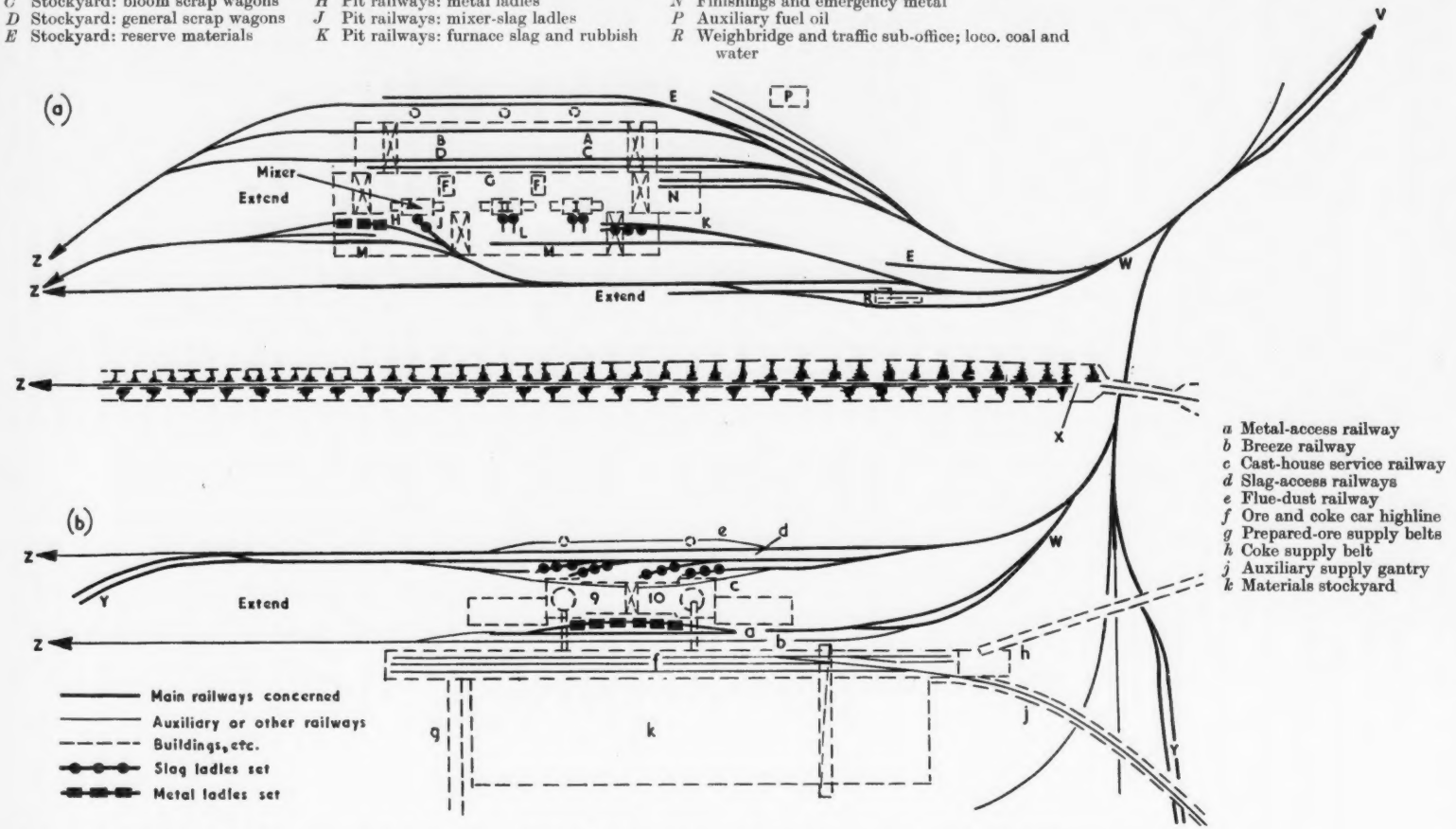
Curves and Clearances

Although a few curves of about 120 ft. radius remain in plain track, an effective minimum of 240 ft. radius has been adopted with 1 in 5 crossings. Extensive use is made of 340 ft. radius with 1 in 6 crossings, and the aim in open surroundings is easier curvature with 1 in 7 or 1 in 8 crossings. Special attention has been paid recently to the sighting lines inside curves, to ensure direct view between drivers and shunters at the opposite ends of trains, and building projects have been modified for this purpose. The normal track spacing with 11 ft. 2 in. centres and 6-ft. walkways gives only 4 ft. 1 in. from rail edge to a 9-ft. wide wagon, or 2 ft. 2 in. between two such wagons, and is considered a minimum. For trackside obstructions, the desirable clearance is now accepted as 4 ft. 5 in. from rail edge, or 7 ft. from track centre. Where lighting poles are situated between railways, the latter then require 15-ft. centres.

Trackwork and Maintenance

All tracks in general use are capable of carrying the axle loads of 30–35 tons arising with ladles and ingot cars. Rails have been mainly of 95-lb. bull-head section, and 109-lb. flat-bottom section is now being introduced. Sleepers are mainly of plain 9-in. × 3-in. channel from the section mills. Special trackwork includes about 800 simple turnouts, plus two tandem turnouts in obsolescent positions, and one diamond crossing without single or double slips. Concentration on simple turnouts has been deliberate, so as to reduce maintenance and shunting errors. Most points are controlled by spring-lever boxes for automatic resetting when trailed through, but a number of reversible point balls remain in older areas. Although shunters normally set points for their own trains, and do not expect to find them in any prearranged direction, there are a few non-reversible point balls that always guide traffic into catch sidings or the correct side of passing loops, unless deliberately held up. Uniform location of point levers is desirable, to avoid shunters passing unnecessarily in front of trains, and single ladders of sidings are preferred for this reason

A Stockyard: oxide wagons
B Stockyard: limestone wagons
C Stockyard: bloom scrap wagons
D Stockyard: general scrap wagons
E Stockyard: reserve materials
F Revolving ground-type chargers
G Valve arch railway
H Pit railways: metal ladles
J Pit railways: mixer-slag ladles
K Pit railways: furnace slag and rubbish
L Pit railways: furnace-slag crane transfer
M Pit railways: ingot teeming
N Finishings and emergency metal
P Auxiliary fuel oil
R Weighbridge and traffic sub-office; loco. coal and water



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g Prepared-ore supply belts
h Coke supply belt
j Auxiliary supply gantry
k Materials stockyard

V Ingots to Frodingham Mill; slag to steelworks bank; scrap from mill; melting-shop materials from Appleby Steelworks sidings
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Fig. 2—(*a*) Railways at Frodingham Melting Shop; (*b*) slag and met railways at South Ironworks

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Fault	Weekly Average
Track or points	3·0
Rolling stock	1·4
Shunting or lock buffering	5·5
Loading, slag tipping, slag or other material on track	5·2
Unknown	1·6
	16·7

The problems of combining desirable railway principles with other plant requirements are complex, and require consideration from the initial stages of works developments. Figure 2*a* shows the very simple railway arrangements at the Frodingham Melting Shop opened in 1947 with bench-type charging for solid materials, mixer for main hot-metal charge, two 300-ton tilting furnaces with subsequent outputs of over 7000 ingot tons/week, and provision for southward extension. Figure 2*b* shows part of the South Ironworks, where slag railways have recently been rearranged to give independent approaches for two groups of three 300-cu. ft. ladles to each furnace, with emergency access preserved by a continuation of one approach to one furnace, and a train-length space between the two turnouts leading to the other furnace. At each of the furnaces now under construction there will be access for two groups of four slag ladles and for four metal ladles.

SIGNALLING AND LIGHTING

The complete and interlocked signalling of works railways is impracticable, and locomotive drivers usually rely on their own attention to surroundings, on coded locomotive whistles for certain movements, and on hand, lamp, or whistle signs from their shunters. At Appleby-Frodingham, traffic continues under this system by day and night, and to 95% of normal in fog. Unintentional contacts by locomotives, mainly without major damage, average once every 12,000 working hours. Common but incomplete use of distant regulation for train movements would be an additional source of danger, and auxiliary aids have, therefore, been confined to definitely exceptional positions. Signal lights are operated by shunters to relay calling-on signs where long trains are weighed, or in certain places where the driver has a restricted view. Signal lights worked by the shunters are interconnected between the two ends of the local-ore subway, and similar lights on the approaches to mill loading bays are interconnected with warning lights inside.

Lighting is important for railways worked mainly by visual attention to surroundings. The usual arrangement is to have poles of 20 ft. height to fittings, at 120 ft. spacing, with fittings on all or alternate poles, according to ground conditions. Compared with occasional high floodlights, this local lighting has the overriding advantage of remaining visible in fog, as a series of trackside landmarks.

WEIGHBRIDGES

There are 17 railway weighbridges, including two combined with wagon tipplers, the main type having 18 ft. platform length, 100 tons capacity, and 50 tons dial reading. Long weighbridges for outward products have triple 16- or 18-ft. platforms with 100 tons individual capacity, 100 tons combined dial reading, and ticket-printer gear. Extra heavy weighbridges for hot-metal ladles and ingot-casting cars have double 11-ft. and 14-ft. platforms with 200 tons individual capacity, 150 tons combined dial reading, and ticket-printer gear.

WORKS WAGONS

The Appleby-Frodingham works wagons are classified in Table III. The total has changed little since 1939, although the average size has been increased by alterations and replacements.

For the primary traffic from the local mines, the 21-ton hoppers are being supplemented by a new 31-ton doorless type. The 30-ton hoppers were bought in 1939 for the redistribution of prepared ore, and older hoppers have since been rebuilt with 18–24 tons capacity for this less permanent traffic. The coke hoppers are of recent design, with nearly 1500 cu. ft. volume, and the dust wagons have been recently rebuilt. The breeze hoppers were bought second-hand during the war, and are the only wooden wagons introduced for many years.

For the ordinary traffic, the pre-war wagons were mainly low-capacity wooden types. Steel-framed wagons built early in the century were used for the heavier and rougher loads, however, and their superior performance led to a policy of substituting modern all-steel wagons for scrap and pig-caster traffic.

A standard chassis for 30-ton internal loads was designed in 1940 with a substantial frame of normal type, 20½ ft. overall length, four wheels on 9-ft. wheelbase, and 10–11 tons tare, including body. Small numbers built during the war had flat decks with positioning lugs for double-deck trays of scrap in charger boxes, plain 12-in. channel sides with no doors for pit scrap, 24-in. plated sides with no doors for slab scrap, or 36-in. plated sides with no doors for pig-caster traffic to cooling and trans-shipment. Larger groups of these wagons were built after the war, and the early steel-framed wagons were then rebuilt and converted for lighter 15-ton loads in general service traffic. More recently, new 30-ton general service wagons (*see* Fig. 3) have been built on the standard chassis, with 490 cu. ft. volume and 48-in. plated sides continuous over 36-in. × 48-in. doors, to replace most of the wooden wagons. The 15-ton side-tip wagons were obtained for wartime re-haulage of cold slag, and are now used for furnace wreckage so long as tipping space remains nearby. Provision for steel-section traffic to structural or similar processes has been made with new quad-bolster wagons (*see* Fig. 3) of 33 ft. overall length and 17½-ft. wheelbase, on an elongated form of the standard 30-ton chassis. Similar steel-plate traffic required a very small number of 30-ton bogie wagons

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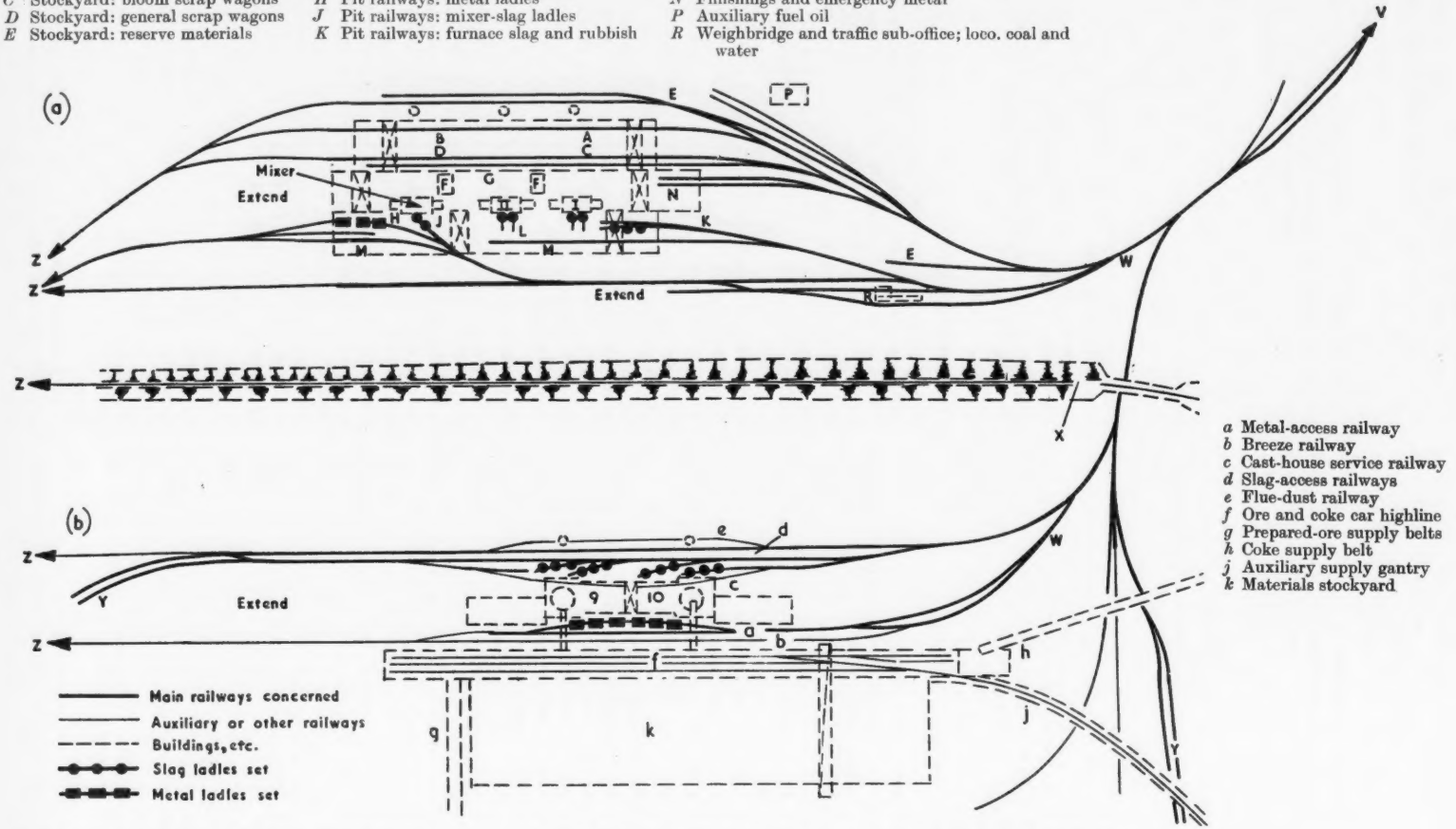

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XUM

Table III
WAGON DETAILS

Type	Size	No. of Wheels	Frames	Number	
Primary Traffic					
Local mines hoppers	21 tons	4	Steel	549	
Prepared ore hoppers	30 ,,	4	,,	25	
,, ,, ,,	18–24 ,,	4	,,	265	907
Coke hoppers	20 ,,	4	,,	18	
Breeze hoppers	20 ,,	4	Wood	32	
Dust wagons	20 ,,	4	Steel	18	
Ordinary Traffic					
Scrap and pig-caster wagons	30 tons	4	Steel	207	
General-purpose wagons	30 ,,	4	,,	80	
,, ,, ,,	15 ,,	4	,,	113	
,, ,, ,,	8 ,,	4	,,	58	580
Side-tip wagons	15 ,,	4	,,	48	
Quad-bolster wagons	30 ,,	4	,,	31	
Plate wagons	30 ,,	8	,,	6	
Specialized wagons	Various	4	Various	37	
Hot Traffic					
Ironworks steam-tip slag ladles	300 cu. ft.	8	Steel	11	
,, rope-tip ,, ,,	300 ,, ,,	4	,,	8	
,, rope-tip ,, ,,	220 ,, ,,	4	,,	7	
,, chain-tip ,, ,,	Small	4	,,	91	354
Steelworks rope-tip slag ladles	220 cu. ft.	4	,,	29	
Hot-metal carriages	70 tons	8	,,	20	
Ingot-casting cars	64 ,,	4	,,	188	
	Total				1841

of 48 ft. overall length, which were obtained second-hand.

For the hot traffic, the special rolling-stock includes newly developed 300-cu. ft. ironworks-slag ladles (*see* Fig. 4) with short 18 ft. 8 in. overall length and rope action over a large quadrant instead of a small top pulley. The bogie crocodile hot-metal ladles and the ingot-casting cars (*see* Fig. 5) are mostly equipped with roller bearings.

Wagon overhauls and recent building are undertaken in a bay of the Central Engineering Workshops. The loads carried per wagon per week, as calculated from Tables I and III, without correction for numbers under repair or the minor internal use of main-line wagons, are 5·5 in primary traffic and 2·8 in ordinary traffic. The corresponding average of 12·0 in hot traffic includes 34·2 for the larger slag ladles, 14·8 for the smaller slag ladles used partly for standby or slow-cooling purposes, 19·6 for the hot-metal ladles, and 6·6 for the ingot-casting cars, whose circulation is restricted to assist mould cooling.

WORKS LOCOMOTIVES

The Appleby-Frodingham fleet included 63 locomotives at the end of the war, but changes in operation and maintenance have since reduced the total to 57, including two of obsolescent type in dead storage. The 55 effective locomotives are of three main types (*see* Table IV); they are all six-coupled, with outside cylinders and a steam pressure of 180 lb./sq. in.

The light type is used mainly at North Ironworks, where gantry loads are restricted, and for level shunting in the Frodingham Mill area. The heavy type was introduced for uphill ore traffic in 1921, and was intended for wider use from 1934. The medium type that followed in 1936 has, however, proved more adaptable and fully adequate for a wide range of uses. All post-war additions have been of this type (*see* Fig. 5).

Operation is based on 43 locomotive duties, of which there are six on daywork, five on two shifts, and 32 on three shifts. Locomotives and men are allocated by the day or shift to these duties, which

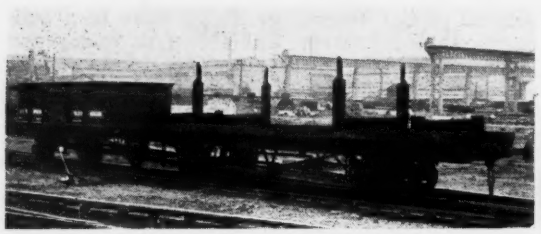

Fig. 3—(*Left*) Internal 30-ton general-service wagon; (*right*) internal 30-ton quad-bolster wagon

Fig. 4—(*Left*) 300-cu. ft. rope-tipped slag ladle; (*centre*) 220-cu. ft. rope-tipped slag ladle; (*right*) 300-cu. ft. steam-tipped slag ladle

are named from the plant or area mainly served, but are subject to diversion to suit immediate needs. Locomotives on day or two-shift duties return each night to the running sheds at Appleby Steelworks or Frodingham Ironworks for fire dropping and relighting, and tank and bunker filling by shed men. Those on all duties are also released at approximately 9-day intervals for shed-day attention; this normally occupies 24 hr. from 9 p.m., for cooling and tank and bunker filling at night, followed by boiler washing-out, tube sweeping, general cleaning, and mechanical adjustments under daytime supervision, and relighting and steaming in the evening. The duties are grouped by location and type of locomotive required into six rotas; three are based on each shed, and each rota includes a bye-turn locomotive to replace the others in turn. A standby locomotive is kept in steam at each shed for shed transfers and the previously important replacement of breakdowns, and four locomotives are normally under overhaul. Present allocation of the 55 locomotives is, therefore, 78% in operation, 11% for bye-turning, 4% as standby, and 7% under overhaul. A central shed is now under construction, and this, together with improved locomotive condition, will allow a regrouping of duties into four rotas, giving release at approximately 12-day intervals. The fleet requirements will then be 52 locomotives, with 43 (= 82%) in operation, 4 (= 8%) for bye-turning, 1 (= 2%) as standby, and 4 (= 8%) under overhaul.

Breakdowns have now been reduced to an insignificant level by maintenance, which includes light overhauls after 12–18 months in service and heavier overhauls after a further 24–30 months. Total overhauls average 30 per year, with four proceeding together in the Central Engineering Workshops. Advance programmes are used to indicate dates for special examination, and locomotives are then withdrawn to suit actual and relative conditions and workshop programmes.

Locomotive crews consist of a driver and one shunter, the drivers being recruited from shunters with about 12 years' service. Coaling and watering during operational time are undertaken by the crews, at 15 coal and water stations, including the two sheds. The locomotive coal consumption of 1·8 cwt./hr., measured by summer figures when other works consumption from the stages is small, is not unfavourable

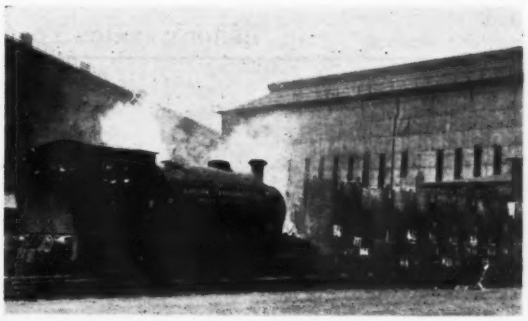

Fig. 5—Medium-sized (16 in.) locomotive, and castings cars with ingots in moulds

for heavy and mainly uphill work. Coaling from stages, mainly before the end of shift and the mid-shift mealtime, is partly into the firebox and partly into the bunker for later use. The new shed will include mechanical bunker-filling, to reduce coaling time and permit more even firing without double handling. Fire cleaning is mainly done before mealtimes, and main oiling and general examination before the end of shift, wherever possible, so as to use times less suitable for running purposes away from shift-changing positions.

Time studies of locomotives on main duties, for the primary, ordinary, and hot traffic, are given in Table V, in which the final column takes some account of other locomotives.

Total operating time, on the usual costing basis, which includes shiftwork mealtimes but excludes day-work mealtimes, is about 6053 locomotive hours per week; this includes about 2012 for primary traffic, 1905 for ordinary traffic, and 2136 for hot traffic. Comparison with Table I shows the net traffic-tons hauled per loco.-hr. to be 76 for primary traffic, 28 for ordinary traffic, and 29 for hot traffic. Similar comparison shows the gross traffic ton-miles per loco.-hr. to average 159, if the route haulage given is increased by, say, 10% for primary traffic, 40% for ordinary traffic, and 10% for hot traffic, to cover shunting movements. Mileage clocks on many locomotives show an average speed of 1·6 m.p.h. during total operational time, and this can reasonably be assessed as 3·3 m.p.h. during the 33% of time running

Table IV
DETAILS OF LOCOMOTIVES

Type	Light		Medium	Heavy	
Number available	1	13	32	2	7
Date built	1910	1917–40	1936–51	1921–27	1934–38
Cylinder dimensions, in.	16 × 24	15 × 22	16 × 24	18 × 24	18 × 24
Wheel dia., in.	45	41	44	48	44
Tractive effort, lb. at 75%	18,432	16,299	18,851	21,870	23,858
Weight full, tons	41	35	50	54	60
Grate area, sq. ft.	14	14	16	18	18
Total heating surface, sq. ft.	742	667	859	1092	1072
Ratio, weight full, lb., to tractive effort, lb.	5·0	4·8	6·1	5·5	5·6
Ratio, tractive effort, lb., to total heating, sq. ft.	24·8	24·4	21·9	20·0	22·3

Table V

SHORT-PERIOD LOCOMOTIVE TIME STUDIES

Allocation of Gross Locomotive Time	Ore Haulage to Crushers		Plate-Mill Shunting and Dispatch		South Ironworks Slag Disposal		Typical Allocation, %
	Min.	%	Min.	%	Min.	%	
Haulage Working Time							
Running with loaded wagons	142	39·0	115	35·0	67	29·6	33
Running with empty wagons	104		53		75		
Running Light	117	18·6	59	12·3	29	6·1	10
Auxiliary Working Time							
Weighing wagons or tipping ladles	24	9·7	43	16·0	125	30·6	22
Shunter at brakes, couplings, points	37		34		22		
Delays							
Route obstructions	19	20·8	6	16·5	13	10·6	14
Instructions, enquiries, examining	7		28		2		
Wagons not ready	62		...		...		
Work completed, miscellaneous	43		45		36		
Servicing							
Coaling and firing	39	11·9	15	12·9	26	15·8	14
Grate cleaning	...		9		8		
Watering	11		10		8		
Oiling	18		25		30		
Fetching stores, miscellaneous	7		3		4		
Mealtimes (shiftwork locos)	...	...	35	7·3	35	7·3	7
Total	630	100	480	100	480	100	100

with wagons, plus 5 m.p.h. during the 10% of time running light. The 159 gross ton-miles per loco.-hr. indicate about 480 gross ton-miles hauled per hour during the relevant 33% of time running with wagons. The average locomotive speed of 3·3 m.p.h. during this time then indicates an average train load of $480/3{\cdot}3 = 145$ gross tons whenever wagons are hauled. This average weight is evidently determined by the diversity and continuity required in traffic operation rather than by maximum locomotive capabilities, and the true average tractive effort required is consequently moderate, even at a large works with adverse gradients. At Appleby-Frodingham these circumstances explain the main and increasing use made of the medium locomotives, and the reservation of the heavy class for special duties where peak efforts cannot be avoided.

The advantages of Diesel locomotives are being investigated carefully, and are at present judged in the following way.

The medium steam locomotive with good normal characteristics gives about 18,850 lb. tractive effort from start to 4 m.p.h., 14,800 lb. at 6 m.p.h., and 8,600 lb. at 12 m.p.h., corresponding to 200 h.p. at 4 m.p.h., 235 h.p. at 6 m.p.h., and 275 h.p. at 12 m.p.h., at rail. Speeds above 12 m.p.h. are unimportant, but great importance is attached to reaching 6 m.p.h. rapidly and maintaining this speed against prevailing inclines. Reliable use of the higher efforts, under a wide range of conditions, requires a weight of 50 tons in full working order. The equivalent weight of a Diesel locomotive, with a smaller range of fuel and water contents, would be 45 tons for braking purposes. Equivalent performance at 6 m.p.h. would require 235 h.p. at rail, from an engine unit of about 300 h.p., plus the margin considered desirable above rating.

For the weight and power required, a Diesel locomotive would cost about twice as much as the steam type. Fuel would be used in close proportion to work done, whereas steam locomotives consume at a more constant rate, lowest in relation to work done when this itself is relatively heavy and on a three-shift basis. Under Appleby-Frodingham conditions, the fuel-saving from Diesel locomotives would be substantial, but would not alone be sufficient to justify the higher capital cost.

Diesel locomotives in general use, and not only in subsidiary use, would avoid most of the present running-shed costs. The maintenance of engine and transmission units is likely to be less than that of present boiler and motion units, but the difference will be small where boiler repair conditions are now satisfactory. Chassis and running-gear items are heavy for all locomotives, particularly where rigid six-coupled wheelbases are used on frequent curves,

and further savings could result from Diesel layout allowing a four-coupled wheelbase of length sufficient for steady running.

Daily availability would be higher with Diesel locomotives. With 43 in operation and a total of six for standby, shed-day, and overhaul purposes, the availability would be 88% instead of the 82% possible with steam types. The servicing time, which now occupies 14% of each shift, would also be reduced, and Diesel locomotives would offer about 50 min. additional working time per shift. It is expected, however, that mechanical bunker filling and some improvement of traditional oiling arrangements will reduce the servicing time of steam locomotives by about 25 min. per shift.

Diesel locomotives would avoid or reduce smoke, steam, and noise in works surroundings. Some smoke reduction has been obtained from assisted turbulence in steam-locomotive fireboxes, however, and Diesel fumes are not without their problems. Diesel cab conditions are attractively clean, but the absence of plentiful firebox warmth prevents the open door and window conditions that now assist driving view and shunters' access. Continuous engine noise may also limit verbal or whistle communication from shunters at a distance.

Subject to the wider question of relying on foreign fuel, there should now be a satisfactory return from the general use of Diesel locomotives in a works or large part of a works. This implies their preliminary introduction into mainly steam fleets for lengthy trial and local experience, and two Diesel locomotives are to be obtained for Appleby-Frodingham when replacements again become necessary.

WAGON STANDAGE AND TERMINAL TIME

For the Appleby-Frodingham traffic (*see* Table I), with weekly arrival of 4390 loads and weekly departure of 640 loads in re-used empties and 1560 in received empties, the average free terminal time is only 1·26 days. This stringent limit is not regularly attainable under conditions affected by:

(i) Variation of works material and fuel consumption
(ii) Seasonal, weekly, or week-end variation of arrivals
(iii) Unsuitability of home ore for storage before preparation
(iv) Sampling, grading, or blending of other arrivals, preventing direct use or bulk storage
(v) Loading of heavier products before delay for inspection or completion of consignments, to avoid rehandling.

During the last financial year, the actual weekly terminal time for the inward and outward traffic concerned averaged 1·5 days, with 1·1 days minimum and 2·1 days maximum.

Extensive hire of main-line wagons for internal traffic is considered undesirable because of the payments involved and the effects on main-line traffic. Limited hire is found to be economic, however, for peak internal traffic, or for loading from stock when external supplies are subnormal.

MATERIALS DISPOSAL

At Appleby-Frodingham the unloading of inward material and fuel is normally undertaken by the consuming departments concerned. The ironworks ore-preparation plant can gradually accept excess arrivals and accumulate up to 160,000 tons in stock. At other destinations, unloading is for direct use, or into plant storage, which is varied only for process reasons. Such unloading arrangements allow compact processes with regular throughput, but require storage elsewhere to balance irregular arrivals.

In this connection, the Traffic Department operates a central stockground service for many inward and some internal materials. To avoid the wide dispersal of materials and handling machinery, the stocks have been concentrated in two main areas, located near the railway entrances *C* and *E* to minimize the extra haulage for stock transfers, and to ensure regular quantities for the main hauls to plant destinations. Together, the two stockgrounds cover about 60 acres and hold up to 250,000 tons. Handling is by caterpillar cranes working on level runways to either side of fixed railways spaced 120–160 ft. apart. A stockbank behind each runway has a triangular cross-section and a usual length of 1000 ft., subdivided into separate heaps of about ten wagon lengths.

Materials are held in about 30 distinct varieties, including oven coal of eight grades, each in three age groups, other coal of three types, breeze in three sizes, steelworks magnetic or other ore, steelworks scale, and certain grades of slag.

The total weekly tonnage unloaded and reloaded may be as high as 12,000 tons, and averages 6000 tons. Six cranes are available, usually five in use and one free for repairs. Three small Diesel cranes, with 30-ft. jibs and 20–27-cu. ft. grabs, are used for small or smooth materials, and will each unload up to 18 wagons or reload up to 36 wagons in a shift. A fourth Diesel crane, with a 50-ft. jib and a 36–45-cu. ft. grab, will handle coke with about the same performance. The fifth crane is a steam face shovel used to load hot-tipped mixer slag or, with a 65-in. magnet added, to handle steelworks foreign ore. The sixth crane, a new Diesel unit with a 45-ft. jib and a 65–81-cu. ft. grab, is already showing over 50% increase of capacity for fuel, and ability to handle rough materials. As the large grab can penetrate material in wagons when lowered steadily, without dropping, it is also proving light on wagon damages. The total crane time has averaged 300 hr./week, and the overall performance, reduced by servicing, travelling between separate heaps, cleaning up or preparing new ground, and shunting interruptions or occasional unrequired intervals, has averaged 20 tons/crane hr.

Many alternative handling methods have been considered from the point of view of cost, peak capacity, flexibility, reliability in all weathers including fog, size and shape of storage heaps, and effects on material handled. Those with fixed plant and high capital cost have been precluded by the wide difference between holding and handling requirements. Several mobile methods are attractive for selected purposes, particularly tippler unloading, with stockpiling by motor vehicle for firm materials. There are major advantages in retaining a single handling method with freely allocated capacity, however, and present methods offer the widest capabilities.

The Traffic Department is also concerned with the disposal of works rubbish. Weekly quantities vary considerably, but include about 2000 tons of slurry

XUM

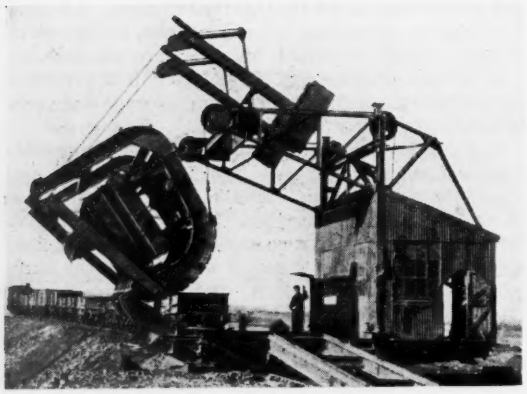

Fig. 6—Mobile wagon tippler at rubbish tip

in tank wagons, about 1700 tons of hard rubbish in side-tip wagons, about 2200 tons of hard rubbish or unsinterable dust in wagons to a mobile tippler, and about 800 tons of special or recoverable material unloaded by hand.

The mobile tippler (*see* Fig. 6) is used at a rubbish bank about 880 yd. long and 25 ft. deep, in an open-cast mined area. The tilting cradle is carried on a low four-wheeled trolley, from which 1 in 10 ramps lead down to the single railway used also for wagon movements. This railway is at least 8 ft. behind the bank edge, and the front corners of the trolley are supported by screwdown jacks joined by a weight-spreading raft. A cab at the back contains a Diesel engine, a tilting winch, and a haulage winch that is used to move the tippler about 17 ft. along the bank after a train of about 160 tons has been emptied. Locomotive power is used to push the train over the ramps in uncoupled wagon lengths, and then to draw the empties back together for immediate return to the works. When accessible space has been filled, the railway is slewed about 7 ft. forward, mainly in its middle length, as the bank was formed concave in plan, to become gradually straight and finally convex. The mobile tippler has proved well suited to a wide range of materials and wagons. Moving parts are slow and simple, and the manpower required is low. Capacity could probably reach 1000 tons/shift, if required, and it is possible to select the material tipped in upper and lower layers at each position along the bank.

RECORDING

The recording of works traffic is undertaken from the weighbridges and a records section of the central traffic office. The main information used for operational purposes or forwarded to general office departments concerned with external supplies, works costs, wages, and railway charges, is as follows:

Sidings Number-taking—Details of full and empty wagons in inward or outward train formation are recorded as evidence of arrival or departure and for the advance preparation of inward weight and tare books. Daily summaries classify the arrival and departure of loads and empties.

Weighing—To reduce weighing time, all inward or internal weights and corresponding tares are entered in train order into preliminary weighbooks. Entries are then transferred to tickets and forwarded by pneumatic post. Outward weighing and corresponding tareing are direct to tickets by weighbridge printer.

Wagon Examining—All wagons are examined for defects or damage on arrival or departure and at strategic internal points.

Wagon Stocktaking—Figures based on daily additions and subtractions can contain cumulative errors; a new physical stocktaking of all wagons present is, therefore, made early each morning. Wagons with main inward and outward loads are only counted, but miscellaneous and internal loads are recorded in detail.

Standage Charges—The sidings and stocktaking summaries are balanced daily with those for unloading and loading, to show the numbers of wagons standing in relation to those allowed free of charge. The daily figures are forwarded to loading and unloading departments. Weekly addition shows the total works standage charge as a balance of debits to some departments and credits to others. These items appear in departmental costs, with the reservation that all credits have to be reduced proportionately if their total exceeds the total debits.

Other Charges—A carbon duplicate record is started for each special or misused main-line wagon from the date of first appearance, and kept until after departure. Daily one-line entries, showing any charges incurred, are circulated to departments or traffic areas concerned. Similar records and advices, showing no charges, are used for wagons already included in standage records but carrying miscellaneous goods and requiring individual attention. A corresponding system, with cards bearing permanent number tabs and lasting six weeks, is used for all internal wagons except those in local and prepared ore traffic. Entries include dummy demurrage at 2*s.* 0*d.* per day where loading, movement, or unloading exceed one day each, and these charges appear as memo items in departmental costs.

Movement Records—Movements of individual wagons are only recorded on arrival and departure, or by morning positions of the less regular loads. Great importance is attached, however, to summaries that confirm the number of loads or trains handled for main traffic operations in each day or shift.

Locomotive and Crane Records—Standardized shift reports from the traffic foremen show the locomotive on each duty, the men on each locomotive, and the time charged to each operation. Similar records are kept for the stockground cranes.

ORGANIZATION

At Appleby-Frodingham the traffic management, which is responsible to the general works management, has a main duty of providing economic traffic service to meet the requirements of all other departments. Traffic organization is broadly through the following channels:

Traffic Manager with Senior and Junior Assistant

Traffic Section	*Clerical Section*	*General Section*
Main and assistant traffic foremen, loco. drivers and shunters	Clerical assistant, clerks, weighmen, examiners, and numbertakers	Foreman and assistant, stockground crane and rubbish tippler men, general and bye-turn labour.

Emphasis is placed on widely spread authority and responsibility, with central guidance on principle, check on performance, and provision of necessary information. For this purpose, the main traffic section has been developed in areas, each with subsidiary organization for a number of locomotive duties and traffic operations. Although they generally follow plant outlines, the areas have been adapted to include

suitable combinations of urgent and non-urgent work, and to allow overlap for the undivided control of main through movements.

The traffic foremen are immediately responsible for following the general arrangements of their own department and co-operating with other departments served. Their contacts are made during circuits of the working areas or through base points, usually weighbridges with works telephone, pneumatic post, and weighmen able to receive messages. The ratios between weekly foreman hours and weekly locomotive hours is approximately 1826/6053 = 1/3·3, based on experience that one man can control in detail the work of 3–4 locomotives within normal range.

Responsible control on site is considered essential for the maintenance of working standards by methods including full visual appreciation of conditions, good personal approach to men, and giving occasional direct assistance. It also allows the inspection of working surroundings in advance of locomotive attendance, in time often to prevent rather than cure the many possible sources of delay. Furthermore, it allows job instructions to be given to shunters, who are aware of train and route-setting details, rather than to drivers, who should work to movement instructions from their shunters. The use of radio to and from locomotive footplates has been considered carefully, but does not appear likely to replace any of the present organization.

The general arrangements now used to provide traffic service are as follows:

Wagon Labelling—This is a prerequisite of further arrangements for all traffic except hot slag, metal, or ingots. Miscellaneous goods arriving at the works are delivered to the general stores for examination and internal relabelling, if necessary.

Continuous Traffic—Much of the total traffic tonnage, particularly coke-oven and blast-furnace materials or blast-furnace slag, requires locomotives hauling a regular succession of nearly similar trains. Arrangements then consist of making sure that routine is followed, of providing or cancelling marginal journeys to suit quantity changes, and of instructing the selection of materials or grades. The heavy haulage of local ore from works boundaries to the preparation plants is arranged at a meeting each Thursday as a working time-table for the following week. Shunting of the plate-mill loading bays is in fixed sequence by time-table, with wagon details obtained from advance shunting notes. Shunting of the section-mill loading banks is in sequence, depending on material rolled, with bank and wagon details from advance shunting notes.

Intermittent Traffic—The disposal of heavy but variable outputs from large steel-furnaces is by close short-term arrangement with the melting-shops department and priority use of locomotive time in the vicinity. Intermediate time is used for the bulk supply of furnace materials, as the charging method does not require attention by rail at closely determined times. Intermittent traffic arising each day or shift is handled by shunting the many sources and destinations at recognized times, suitably related to each other, and to certain daily transfers of mixed traffic between distant parts of the works.

Irregular Traffic—Shunting is arranged to suit requirements made known or confirmed by advices that are carbon copies of the wagon labels. Special locomotive journeys make railway transport expensive for small urgent consignments, and increasing use is made of road transport for maintenance traffic.

Empties—Supplies to the works are mainly of special types ordered through the railway entrances nearest to the loading requirements. Where reloading is permissible, mineral empties are drawn as required from the larger numbers unloaded. Internal empties in return circuits go directly back to source. Internal empties in free circulation are re-used nearby or collected to area pools, balanced by a sharing of empties from the rubbish tip.

Central Control—As the heavier traffic continues by routine and local arrangement, although the recording system keeps daily check on lighter traffic, there has been no need to establish any comprehensive central control of detailed movements. A continuous independent control exists, however, for the movement and allocation of hot metal from the three ironworks to the two melting shops and the pig-casting plant.

The traffic management is concerned with a broader attention to current progress, from the recording system or by essential inspection on site, and with questions of principle concerning operation or personnel. A short morning conference is held with the main foremen to review wagon standage and material stocking, variation of locomotive duties worked, changes in general arrangements to suit new requirements, or special difficulties arising. Rather low margins are preferred for materials under load, facilities in use, and manpower, since it is found that relative difficulties then lead to corrective measures when still at low absolute level, whereas easy regular margins are soon absorbed in normal performance and no longer in reserve. Other management functions for operation include the formulation of maintenance programmes in conjunction with the engineering departments, and frequent occupation with long-term traffic improvements or developments for a continually expanding works. Other functions concerning personnel include close attention to working conditions and welfare facilities, to manning schedules and holiday lists, which require great uniformity, and to discipline by methods aiming primarily at correct attitudes for the future. Close relations have been established with the union concerned, both for solving specific problems and for routine discussion of performance, conditions, and accident prevention. For this routine purpose, a monthly joint consultation meeting has now been held for ten years, attended by management, foremen, union officials, and other representatives.

CONCLUSION

This account of railway traffic at a steelworks includes factual detail which may form a basis for useful discussion. Although the figures quoted refer to a very large scale of operation, which does not always assist standards of unit performance, an attempt has been made to formulate more general reasons for the methods and practices adopted.

Acknowledgment

The writer is indebted to the management of the Appleby-Frodingham Steel Company for permission to publish the data included in this paper.

XUM

Assessment of Skin Thickness of Rimming Ingots

By S. J. Smith, A.I.M.

SYNOPSIS

By examination of a series of 60 ingots, it is shown that the major factors governing the skin thickness of rimming ingots seem to be teeming rate and rimming characteristics. 716

DURING various investigations on 0·07–0·15% carbon O.H. rimming steels, a series of 60 ingots from 33 different casts was selected for corner sampling at a standard position 24 in. from the base. No deoxidizing additions were made to the moulds. Ingots of three different sizes were used:

5-ton square ingots	...	75 in. × 25 in.
4 ,, ,, ,,	...	65 in. × 24 in.
2½ ,, duodecagonal ingots		65 in. × 20 in. dia.

After suitably preparing the corner sample, the skin thickness protecting the primary blowholes of each ingot was measured, and it was then considered in relation to various steelmaking factors.

RESULTS

The data for individual ingots are given in Table I.

Ingot-rimming characteristics and teeming rate were found to be the major factors related to skin thickness. This is clearly shown in Fig. 1*a*, where skin thickness is compared with teeming rate, as measured under normal works conditions, and rimming characteristics are grouped in three classes: bootlegging/level rimming; rimmers rising + 0–6 in.; and rimmers rising + 6 in. These relationships apply equally to both top-poured and bottom-poured ingots.

In Fig. 1*b* the values of teeming rate and rimming characteristics have been replotted on a basis of log skin thickness *versus* log teeming rate. The result is a series of straight-line graphs of slope $-\frac{1}{2}$; that is,

$$d \propto \frac{1}{\sqrt{TR}}$$

where d = skin thickness (in.) and TR = teeming rate (in./min.). Variance of skin thickness also seems to be related mainly to rimming characteristics.

For any ingot of known skin thickness and known rate of rise, it is possible to calculate the ferrostatic head required to reduce the CO evolution to the point of entrapment.

Let h = ferrostatic head (in.); T = time required to establish ferrostatic head h; R = degree of observed rise during rimming; and K = a constant. Then

$$d^2 = KT,$$

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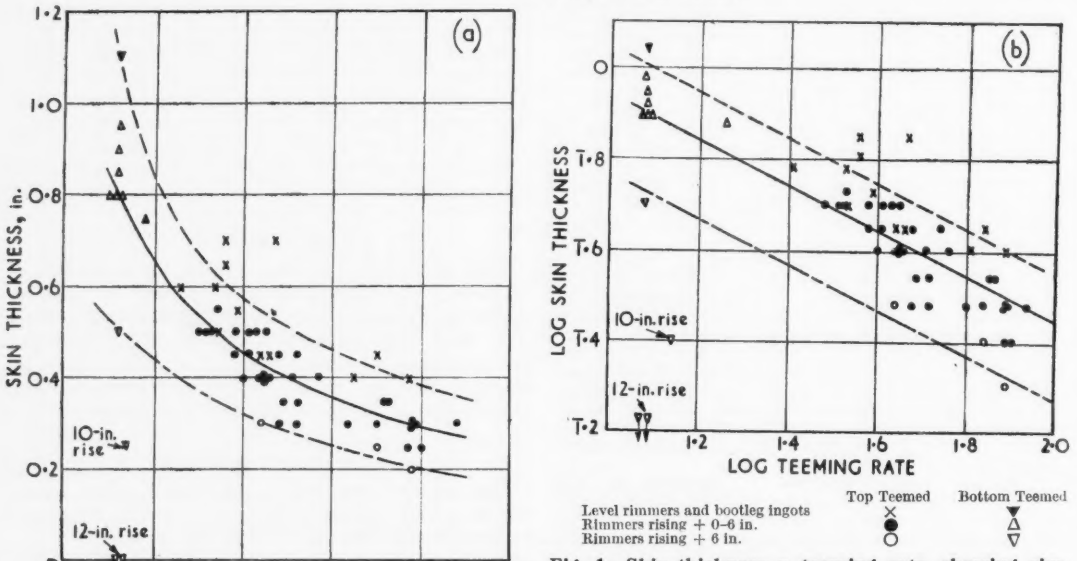


Fig. 1—Skin thickness *v.* teeming rate, showing rimming characteristics: (*a*) Plotted directly; (*b*) plotted on a logarithmic scale

since the rate of solidification is proportional to the square root of time.* Also $h = TR.T$ and therefore

$$Kh = d^2.TR \quad \ldots\ldots (1)$$

* J. W. Spretnak, *Amer. Inst. Min. Met. Eng., Proc. Nat. O.H. Comm.*, 1947, vol. 30, pp. 187–196.

Assume that, for a given state of oxidation, the ferrostatic head is the sole factor controlling skin thickness. Then, from equation (1), d should be inversely proportional to $\sqrt{TR}$. This, in fact, is the finding shown by Fig. 1*b*.

Table I

DATA FOR INGOTS USED

Ingot No.	Type	Teeming Rate, in./min.	Rimmer Rise, in.	Ferrostatic Head × K, in.	Skin Thickness, in.		Tap Temp., °C.	Ladle Skull, tons
					Calculated	Measured		
1	5-ton t.t.	70	9	4·3	0·18	0·25	1600	Nil
2	„ b.t.	12	9	3·0	0·44	0·5	1620	„
3	„ „	12	−2	14·5	1·05	1·1	1615	„
4	„ „	13	12	0	0	0	1610	„
5	„ „	12	12	0	0	0	1615	„
6	„ t.t.	80	6	5·0	0·26	0·25	1600	„
7	„ „	40	5	6·4	0·4	0·4	1600	1·5
8	4-ton „	77	4	4·8	0·31	0·25	1590	Nil
9	5-ton „	78	8	3·1	0·21	0·2	1595	„
10	„ „	63	2	5·7	0·38	0·3	1600	„
11	„ „	57	5	9·1	0·33	0·4	1595	Trace
12	„ „	51	5	8·2	0·35	0·4	1595	„
13	„ b.t.	18	3	10·1	0·68	0·75	1595	„
14	„ t.t.	49	4	6·0	0·39	0·35	1600	0·25
15	„ „	48	2	9·7	0·44	0·45	1600	Nil
16	4-ton „	36	0	15·1	0·56	0·65	1600	„
17	5-ton „	52	4	10·7	0·37	0·45	...	1·0
18	„ „	34	1	10·3	0·55	0·55	1600	1·0
19	„ „	39	−2	11·8	0·58	0·55	1595	1·0
20	„ „	34	0	12·2	0·58	0·6	1595	1·0
21	„ „	52	5	6·4	0·35	0·35	1615	Trace
22	„ „	52	5	4·7	0·3	0·3	1615	„
23	„ b.t.	12	3	7·7	0·83	0·8	1615	„
24	„ „	12	3	7·7	0·83	0·8	1615	„
25	„ t.t.	44	6	7·0	0·35	0·4	1605	0·5
26	„ „	44	8	4·0	0·27	0·3	1605	0·5
27	„ b.t.	12	4	7·7	0·78	0·8	1605	0·5
28	„ t.t.	33	4	8·3	0·47	0·5	1610	1·0
29	„ „	38	3	7·7	0·47	0·45	1590	0·5
30	2½-ton „	70	3	6·4	0·34	0·3	1590	0·5
31	„ „	88	3	8·0	0·31	0·3	1590	0·5
32	5-ton „	46	6	7·4	0·34	0·4	1605	Nil
33	„ „	43	6	10·7	0·35	0·5	1605	„
34	4-ton „	26	0	9·4	0·66	0·6	1605	„
35	2½-ton „	79	4	7·2	0·3	0·3	1605	„
36	„ „	72	3	8·8	0·34	0·35	1605	„
37	„ „	72	3	8·8	0·34	0·35	1605	„
38	5-ton „	36	−12	17·6	0·8	0·7	1595	0·5
39	„ „	45	2	11·2	0·45	0·5	1595	0·5
40	4-ton „	38	2	9·5	0·49	0·5	1595	0·5
41	2½-ton „	65	−4	10·2	0·48	0·4	1595	0·5
42	„ „	70	−12	14·2	0·58	0·45	1595	0·5
43	5-ton „	41	6	8·3	0·36	0·45	1595	1·0
44	4-ton „	30	4	7·5	0·49	0·5	1595	1·0
45	2½-ton „	78	3	7·0	0·33	0·3	1595	1·0
46	„ „	78	3	7·0	0·33	0·3	1595	1·0
47	5-ton „	44	0	8·9	0·51	0·45	1610	1·5
48	„ b.t.	12	1	10·8	0·93	0·95	1610	1·5
49	2½-ton t.t.	77	−1	12·3	0·4	0·4	...	...
50	5-ton „	33	1	8·3	0·56	0·5	1600	1·5
51	„ „	34	0	8·5	0·58	0·5	1605	0·5
52	„ „	45	5	7·2	0·37	0·4	1595	...
53	„ b.t.	12	1	8·7	0·93	0·85	1595	...
54	„ t.t.	41	3	10·2	0·45	0·5	1590	1·0
55	„ b.t.	12	1	9·7	0·93	0·9	1590	1·0
56	„ t.t.	46	0	9·2	0·5	0·45	1590	2·0
57	„ „	48	6	4·3	0·32	0·3	1605	0·25
58	„ „	45	6	7·2	0·34	0·4	1600	Nil
59	„ „	47	−12	23·0	0·7	0·7	1595	2·0
60	„ b.t.	13	10	8·1	0·31	0·25	1610	Nil

t.t. = top teemed
b.t. = bottom teemed

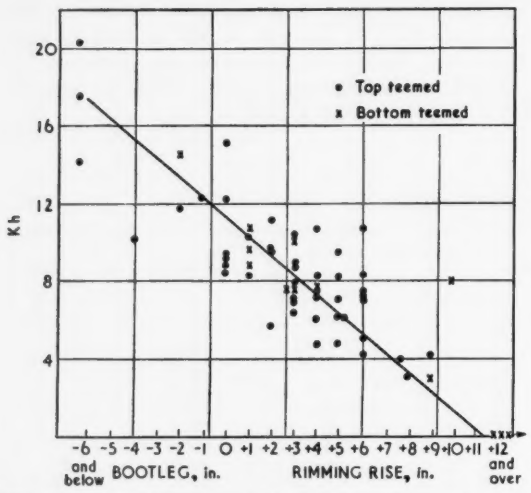


Fig. 2—Calculated ferrostatic head *v.* observed rimming characteristics

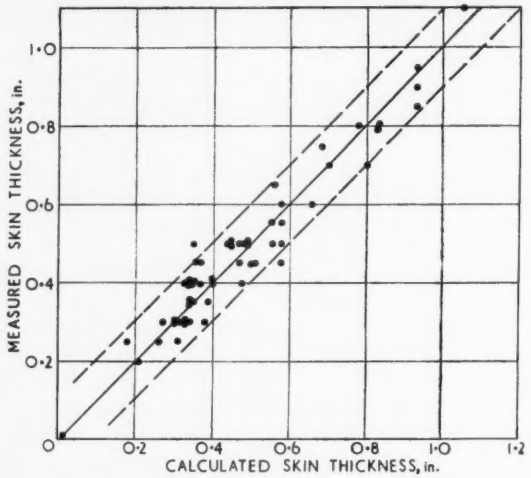


Fig. 3—Measured skin thickness *v.* calculated skin thickness

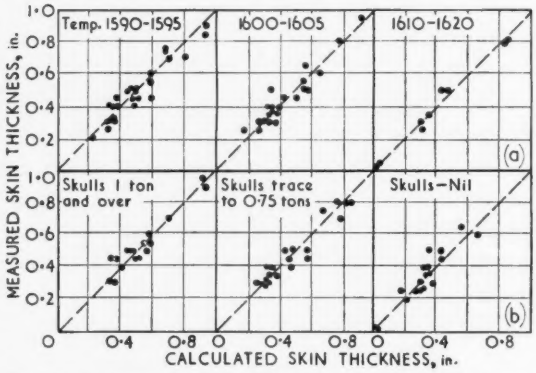


Fig. 4—Measured skin thickness *v.* calculated skin thickness for different temperature ranges: (*a*) Tap temperature; (*b*) ladle skull

For each ingot, the value of Kh has been calculated from the known values of d and TR (Table I). In Fig. 2, this value has been plotted against the observed rimming characteristics expressed as the degree of bootlegging or the degree of rise. The result is a straight-line graph, which again applies to both top-poured and bottom-poured ingots, irrespective of size.

From Fig. 2 is obtained the value:

$$Kh = -R + 11{\cdot}3 \quad \ldots\ldots(2)$$

Thus, from equations (1) and (2),

$$d^2TR = 11{\cdot}3 - R$$

or

$$d = \sqrt{\frac{11{\cdot}3 - R}{TR}} \quad \ldots\ldots(3)$$

In Fig. 3 the calculated skin thickness as derived from this formula has been plotted directly against the measured skin thickness. The agreement is generally within $\pm 0{\cdot}1$ in.

EFFECT OF TEMPERATURE

The tap temperature of the casts involved ranged from 1590° to 1620° C. (Table I).

To determine any effect of temperature on skin thickness (as distinct from effects of temperature on the state of oxidation, which would be reflected in the rimming characteristics), the data in Fig. 3 have been separated into groups, according to both tap temperatures and ladle skulling, and have been replotted in Fig. 4. All groups show equal scatter around the mean line; thus, there is no evidence of any appreciable effect of temperature on skin thickness, within the range involved.

STATISTICAL EXAMINATION OF RESULTS

The correlation coefficient between the measured values of skin thickness and those calculated by means of formula (3) is 0·96; *i.e.*, the formula explains 92% of the skin-thickness variation and gives 95% confidence limits of $\pm 0{\cdot}12$ in. about the mean line.

CONCLUSIONS

The main factors governing the skin thickness of rimming ingots, irrespective of ingot size or casting temperature within the range considered, and irrespective of whether the ingots are top-poured or bottom-poured, seem to be

(1) State of oxidation as indicated by rimming characteristics
(2) Teeming rate.

For the particular ingots and conditions examined, the relationship between skin thickness and these two factors may be expressed in the form:

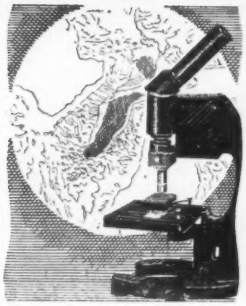
$$d = \sqrt{\frac{11{\cdot}3 - R}{TR}}$$

Calculations of skin thickness from this formula have normally proved to be well within 0·1 in. of the actual skin thickness established by measurement of corner samples.

Acknowledgments

The author wishes to express his thanks to the Directors of Stewarts and Lloyds, Ltd., for their permission to publish this paper, and to his colleagues for their interest and co-operation in carrying out the experimental work.

The Notched Slow-Bend Test as a Brittle-Fracture Test



By

J. E. de Graaf and J. H. van der Veen

SYNOPSIS

The paper gives additional information on the notched slow-bend test, described in a previous paper. The experiments that led to the choice of a 3-mm. deep pressed notch in the standard test, and, in addition, experience with deeper notches, especially in regard to the conditions affecting the arrest of crystalline fracture, are discussed. The phenomena at the root of the notch up to the start of incipient fracture, and those related to the strain distribution in bending are also discussed. Experimental evidence that shows that no unequivocal correlation exists between several of the criteria for brittle fracture is given. This suggests that a test in which the different criteria can be determined separately is preferable. In a statistical analysis of test data, Charpy **V**-notch and notched slow-bend tests are compared, and it is shown that, in quality inspection of plates, the uncertainty of the notched-bend test is less than that of the Charpy **V**-test by a factor of more than 2.

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THE test under consideration is the notched slow-bend test, used by the authors in their investigations of brittle fracture. A description of test performance, criteria, and phenomena encountered is given in a paper[1] that was presented and discussed at the recent Symposium on Notch-Bar Testing. In this paper, several views could be put forward only as statements without proof, and so part of the present paper is concerned with the full experimental evidence for these statements. The other part deals with the results of new experiments, and, finally, the notched slow-bend test and the Charpy **V**-notch impact test are compared, with special regard to their merits as acceptance tests from a statistical point of view.

CHOICE OF NOTCH DEPTH

In the previous paper,[1] it was stated that in the standard test, 3 mm. was chosen for the depth of the pressed notch because deeper notches were severer, in relation to the tendency to start crystalline fracture, than a natural fibrous crack, propagating in the tension half of the specimen.

This statement was based on tests made from 11 1-in. thick steels, using notches 1, 3, 5, and 8 mm. deep and a testing temperature of about 20° C. Many of these steels showed an appreciable scatter of test results, obviously because the testing temperature was rather near the transition temperature for brittle fracture. In some of the bars a fibrous crack would start from the notch, and in other bars from the same steel, crystalline fracture would start immediately at the root of the notch. This scatter was ascribed to fluctuations of steel properties. At first, and as the most likely approximation, the evaluation of the test data was based on the assumption that the average brittleness of every bar from the same steel would be constant, and that the scatter would be caused by fluctuations of the tendency for brittle fracture to have an average wavelength smaller than the length of the fracture path in the bend test. This means that the local brittleness of the steel at the root of the notch was assumed to be a matter of mere chance and not systematically related to the casual brittleness at some distance from the notch. According to this hypothesis, if only 'short-wave' fluctuations are assumed to occur, the chance of starting a crystalline fracture from a fibrous crack before the neutral axis of the specimen is defined as $CBA/100\text{–}CN$, where CN is the percentage of bars starting crystalline at the notch, and CBA is the percentage of bars starting crystalline from a fibrous crack before the neutral axis. In Fig. 1*a*, $CBA/100\text{–}CN$, determined from tests with notches 3 mm. deep, is plotted against the same quantity for bars with 1-mm. notches. As a first approximation, this graph leads to the conclusion that, on the average, the chance of crystalline fracture starting from a fibrous crack in the tension half of the specimen is the same for both notch depths, since the points are almost equally distributed about the 45° line.

To eliminate scatter as much as possible, both quantities were averaged for each of the steels investigated. An average chance, $(CBA/100\text{–}CN)_{1,\,3}$, was obtained and was used as a standard with which the severities of the various notch depths were compared. This has been done in Figs. 1*b–e*, which show that the 5- and 8-mm. notches are more severe than the fibrous crack in the tension half of the bar, and that the 1-mm. notch is far less severe. The 3-mm. notch seems to be only a little less severe than the fibrous

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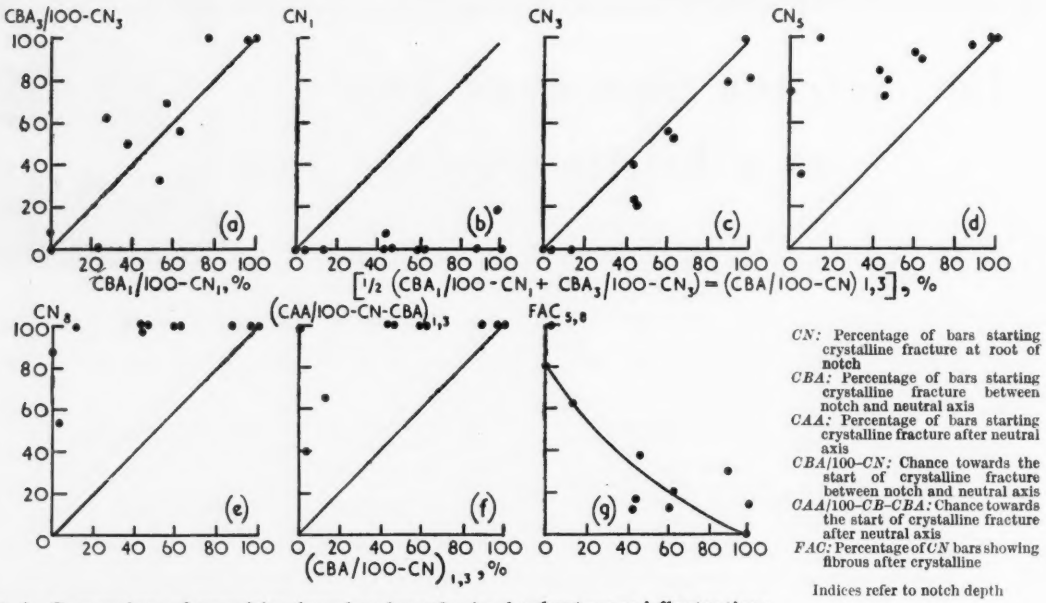
CBA3/100-CN3
CN1
CN3
CN5
(a)
(b)
(c)
(d)
CBA1/100-CN1, %
[1/2 (CBA1/100-CN1 + CBA3/100-CN3) = (CBA/100-CN) 1,3], %
CN8
(CAA/100-CN-CBA)1,3
FAC5,8
(e)
(f)
(g)
(CBA/100-CN)1,3, %
CN: Percentage of bars starting crystalline fracture at root of notch
CBA: Percentage of bars starting crystalline fracture between notch and neutral axis
CAA: Percentage of bars starting crystalline fracture after neutral axis
CBA/100–CN: Chance towards the start of crystalline fracture between notch and neutral axis
CAA/100–CB–CBA: Chance towards the start of crystalline fracture after neutral axis
FAC: Percentage of CN bars showing fibrous after crystalline
Indices refer to notch depth

Fig. 1—Comparison of severities, based on hypothesis of ' short-wave ' fluctuations

crack before the neutral axis of the specimen. In Fig. 1*f*, the compression and tension halves of the specimen are compared. The chance of starting a crystalline fracture in the compression zone is defined as *CAA*/100–*CN*–*CBA*, *CAA* being the percentage of bars starting crystalline fracture after the neutral axis. This graph shows that the tendency to start crystalline in the compression zone is far greater than in the tension half of the bar, and that it seems comparable with the tendency to start crystalline from the root of an 8-mm. notch.

Although both *CN* and *CBA* bars were found at both ends of a plate, which suggests that short-wave fluctuations are still important, the centre of gravity of the *CN* group was nearer the top of the plate than that of the *CBA* group. The same trend was found when comparing *CBA* and *CAA* groups. This suggests that, for instance, the group of *CN* bars will represent a selection from the original batch whose mean brittleness will be greater than that of the bars that show an incipient fibrous crack (the 100–*CN* group). This means that the assumption that the average brittleness of all bars from the same steel is equal is not quite correct; the scatter of test results is not only caused by short-wave fluctuations, but also by fluctuations with a wavelength larger than the dimensions of a single specimen.

Consequently, another comparison was made, based on the hypothesis that the short-wave fluctuations can be neglected, and that the scatter of test results is caused by differences between entirely homogeneous bars due to long-wave fluctuations. In this comparison, the quantity $CN + CBA$ may be chosen as a measure of the severity of the fibrous crack before the neutral axis. This, however, is only allowed when the severity of the notch root is presumed to be smaller than that of the fibrous crack. Some comparisons based on this hypothesis are shown in Fig. 2.

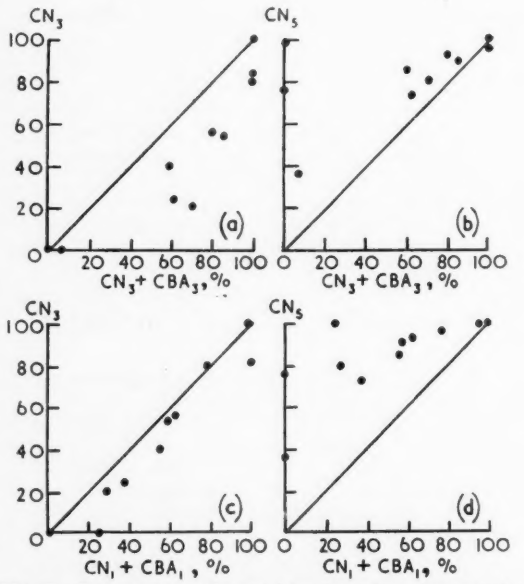

Fig. 2—Comparison of severities based on hypothesis of ' long-wave ' fluctuations. For definition of symbols, see Fig. 1

In these diagrams, the severity level at the root of the notch, determined for notches 3 mm. and 5 mm. deep (CN_3 and CN_5 respectively) is compared with the severity level of the fibrous crack before the neutral axis. The latter quantity was determined from bars with notches 1 mm. and 3 mm. deep ($CN_1 + CBA_1$ and $CN_3 + CBA_3$ respectively). The diagrams show that in both cases of comparison the 3-mm. notch is less and the 5-mm. notch more severe than the fibrous crack.

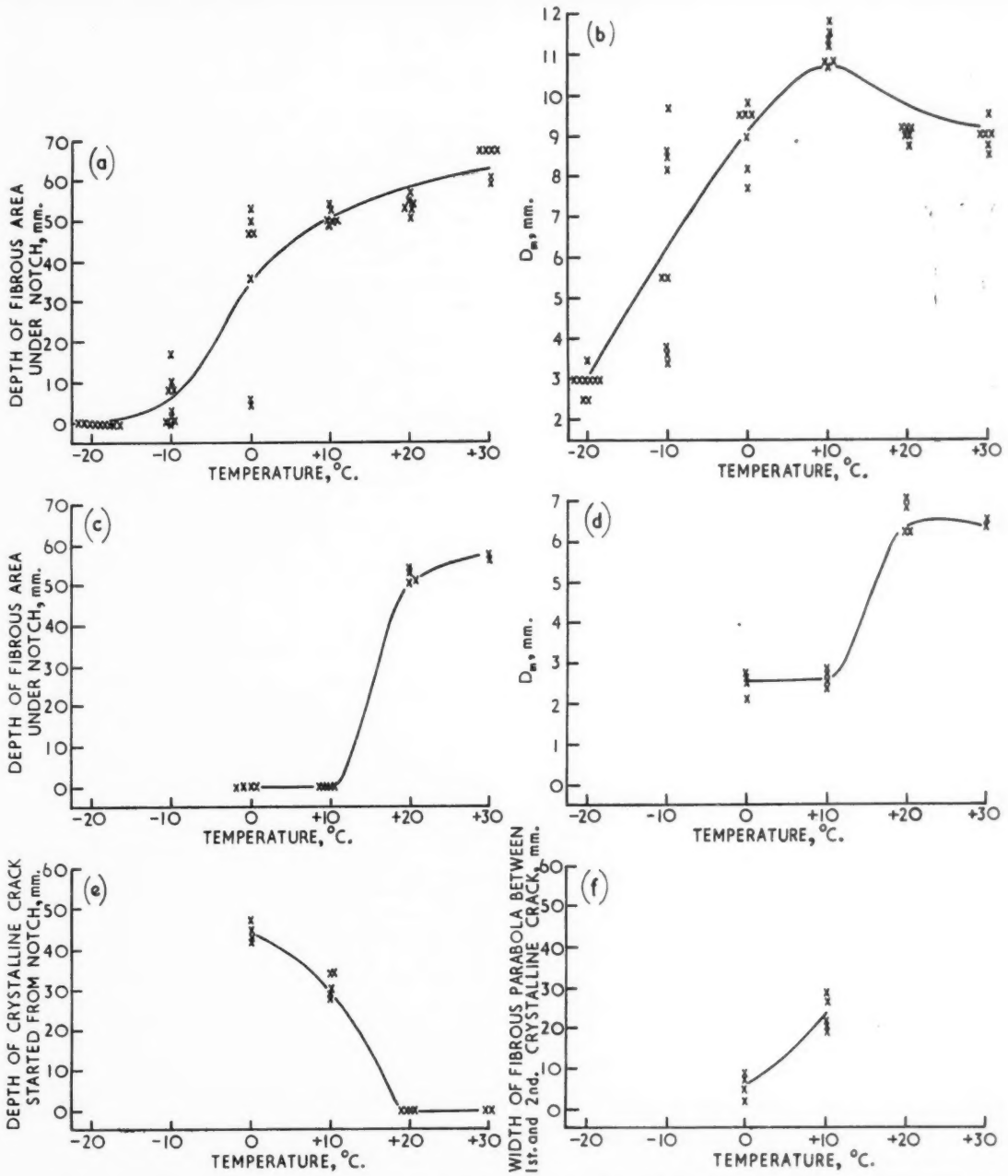

Fig. 3—Transition curves of a 1-in. mild-steel plate for notches (*a*) and (*b*) 3 mm. and (*c*)–(*f*) 8 mm. deep

Thus both ways of comparison (short- and long-wave fluctuations) lead to the same qualitative conclusion. The fact that $CN_3 + CBA_3$ is generally greater than $CN_1 + CBA_1$ may be due to short-wave fluctuations that have been neglected in the second comparison.

Since notches 5 mm. and over in depth are more severe than a fibrous crack in the tension half of the specimen, the occurrence of *d*- and *c*-type fractures* is greatly suppressed when notches of 5 mm. and over in depth are used. In those cases, crystalline fracture generally starts either at the notch (CN) or

* These are fractures in which an initially fibrous crack switches over to the crystalline mode of propagation before the neutral axis of the specimen (*see* Fig. 3 of the previous paper[1]).

after the neutral axis (*CAA*). The fact that crystalline fracture starting between notch and neutral axis is not absolutely suppressed may be due to short-wave heterogeneity, and to the increase in strain hardening of the material caused by the impression of the notch. Because of this strain hardening, not only the tendency to start crystalline fracture at the notch, but also, though to a lesser extent, the tendency to start crystalline fracture from a fibrous crack in the tension zone of the bar will be raised when the notch depth is increased. When deeper notches are used the transition temperatures of the steel are raised. This is shown by Fig. 3, which gives the transition curves for a 1-in. mild-steel plate, obtained from tests with notches 3 mm. and 8 mm. deep. These graphs also show that in this case the start of crystalline fracture, after a fibrous crack depth greater than 0 and less than 32 mm., is completely suppressed when 8-mm. notches are used.

ARREST OF A CRYSTALLINE CRACK

The standard test, in which a notch 3-mm. deep is used, was meant to determine the tendency of the steel to start crystalline fracture from a fibrous crack. That is why in this test the principal criteria described in the previous paper[1] are related to the behaviour of the test specimen up to the point at which the initially fibrous fracture switches over to the crystalline mode of propagation. After this event, a measurable amount of work may be absorbed; this is not measured in the standard test because it is generally relatively unimportant, and is obviously only caused by the crystalline part of the fracture having shear-fractured edges along the plate surfaces, the width of which may vary between 0 and about 2 mm.

On the other hand, it has been found that when a crystalline crack is made to propagate from a deeper notch (5 mm. and over in depth), these fibrous edges may widen as the crack progresses and finally join, thus causing the arrest of the crystalline crack and the appearance of a so-called 'thumb nail' of parabolic shape. After this, the rest of the fracture may be fully fibrous, or may show a sequence of alternate fibrous and crystalline areas. This seems to be in accordance with the experience that notches 5 mm. and over in depth are more severe than a natural crack. These crystalline cracks were obviously arrested because the tendency to brittle fracture decreased in the direction of crack propagation.

This phenomenon may be important in practice for those cases in which the conditions for the start of crystalline fracture, prevailing at the origin of the crack, are more severe than those in the steel plate at some distance from the origin. This may occur when, for instance, the weld metal or the heat-affected zone is more brittle than the unaffected plate material. In view of this, the development of a special test for the tendency to arrest crystalline cracks seemed to be desirable; the same bend test was considered, but with a notch 8 mm. deep and with the transition temperature defined for the tendency to arrest a crystalline crack as 'the testing temperature at which a crystalline crack, started from the notch, would be arrested at the neutral axis of the bar.' Such a test would be simpler, and therefore more suitable for quality inspection, than the Robertson test.[2]

The results of a preliminary investigation in this direction are given in Fig. 3. The transition temperature for the arrest of crystalline fracture, determined from Fig. 3*e*, is about 10° C. higher than the fracture-appearance transition temperature, determined with the standard test (*see* Fig. 3*a*).

The tendency to start crystalline fracture continued to be determined, using the standard notch depth of 3 mm., not only because it was thought to be the most important property, but also for two other reasons. One was that the tendencies to start and to arrest crystalline cracks appeared to be roughly inversely proportional. This was already suggested by Figs. 3*e* and *f*, and confirmed by Fig. 1*g*, which compares both tendencies as determined from the experiments already described. In Fig. 1*g*, the tendency to arrest a crystalline crack is denoted by the quantity $FAC_{5,8}$, *i.e.*, the percentage of *CN* bars showing fibrous after crystalline for tests with 5- and 8-mm. deep notches. There is, however, some scatter among the points of this graph; this is undoubtedly caused partly by the limited number of tests, but, on the other hand, it may point to the fact that the relation between the tendencies to arrest and start a crystalline crack is a little different for different types of steel. In fact, some steels showing about the same tendency to arrest crystalline cracks would differ in the width of the fibrous parabolas separating subsequent patches of crystalline fracture.

The second reason arose from the idea that the propagation of a crystalline crack would require a definite, though small, amount of energy. The tendency to arrest a moving crystalline crack would be related not only to the decrease of brittleness in the direction of crack propagation, but also to the amount of elastic energy accumulated in the vicinity of the future crack path. It was thought that in practice, where more complicated structures of large plates are concerned, the conditions in regard to accumulated energy might differ from those in the test bars under consideration.

In the first series of preliminary experiments on this subject, with a constant notch depth of 8 mm., the amount of elastic energy accumulated in the machine at the start of crystalline fracture was varied. The usual procedure was followed in ten normal bars, and the average depth of the crystalline area under the notch was found to be 22 mm., individual values ranging from 14 to 31 mm. Each of the other bars from the same plate was bent, together with two unnotched dummy bars, which were intended to act as a brake on the discharge of elastic energy. In this case, the average depth of the crystalline crack was 26 mm. (17–30 mm.) and was thus, within the limit of error, identical with the first group. In a third group of ten tests, the load was applied *via* a hard rubber cushion, by which the amount of accumulated elastic energy was raised by a factor of 13. In this case, the average depth of the crystalline crack was 38 mm. (15–61 mm.). Thus, the effect of elastic energy accumulated in the testing machine seems to be rather small in comparison with the scatter, taking into account the fact that the amount

of energy in the previous test series was raised by a factor of 13. The velocity with which this kind of energy can come into effective action is probably not high compared with the speed of propagation of the crack.

In a second small test series, the energy accumulated in the specimen was raised by using tension instead of bending. In this way, the average depth of the crystalline crack was raised from 25 to 45 mm. This, however, need not have been due to an increase of accumulated elastic energy; it may have been caused by the absence of the more fibrous neutral axis in the tension test.

In a third experimental comparison, also designed to give the energy-in-specimen factor, two notched tension tests were compared, one of the specimens being provided with a circular drilled hole, 4 mm. in dia., opposite the notch, the centre of the hole being 4 mm. from the unnotched edge of the bar. This hole caused an increase of crystalline crack depth from 49 mm. to fully crystalline. This, however, may be due either to increased local elastic energy in the bar, or to a concentration of plastic strain in the neighbourhood of the hole.

In a fourth test series, the influence of the fibrous-promoting plate surfaces was diminished by side notches, pressed in the surfaces of the bar along the future crack path; the depth of these notches varied from 0 to 2 mm. By this means, the depth of the crystalline area could be raised from 40 to 57 mm.

In a fifth series of tests, aiming at the factor strain, the bend specimens were pre-strained in tension up to elongations of 8%. In this way, the depth of the crystalline area was raised from 25 to 50 mm. Analogous results were obtained by pre-straining the cross-section of the bar by downward compression of the surfaces along the future crack path, using 5-mm. dia. rolls.

In a sixth series of tests, the normal notch, pressed to the full depth of 8 mm., was compared with a notch that was machined to a depth of 7 mm. and then pressed to the final depth of 8 mm. Instead of a crystalline area 20 mm. deep, observed in the normal tests, an incipient fibrous crack was obtained

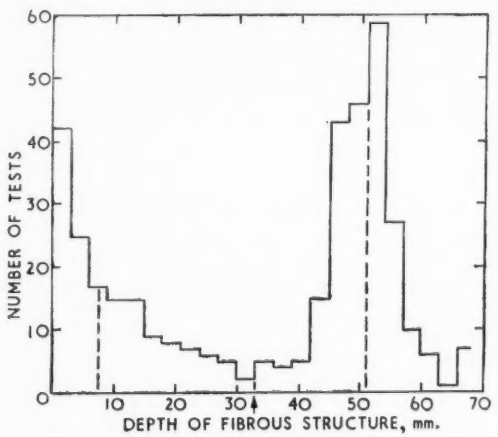

Fig. 4—Distribution of 'mm. fibrous' in transition range (notch depth 3 mm.)

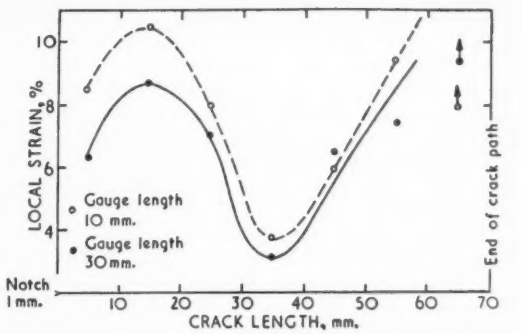

Fig. 5—Local strain as a function of crack length during fibrous fracture (notch depth 1 mm.)

in one of the two bars with pre-machined notches; the other bar showed an incipient crystalline crack only 1·5 mm. deep. This shows that the start of crystalline fracture from an entirely pressed 8-mm. notch is strongly promoted by the severe strain caused by the impression of the notch. Additional experiments showed that a pre-machined notch could be made to cause a 50-mm. deep crystalline crack by pre-straining the test bar in tension up to an elongation of 12%. Thus, the arrest of a crystalline crack, started from a deep pressed notch, seems to be due principally to a strong decrease of brittleness in the direction of crack propagation, caused by the compression strain under the notch.

NEUTRAL AXIS

It has been suggested in the description of the standard test[1] that the tendency to start crystalline fracture has a minimum at the original neutral axis of the bend specimen. This is shown by Fig. 4, which is a histogram of 'mm. fibrous,' *i.e.*, the depth of fibrous structure under the notch. The histogram was originally intended to be composed only of tests made at the exact transition temperatures of each of the 33 plates tested. However, as the testing temperature was usually varied in steps of 10° C., a coincidence of transition temperature and testing temperature was extremely rare. As the best approximation, the histogram was composed only of those tests for which the testing temperature was not more than 5° C. higher or lower than the fracture-appearance transition temperature. In this way, 379 tests were selected, from which the histogram was made. The average value of 'mm. fibrous' in this collection of tests was 33·5 mm., slightly higher than the transition value of 32 mm. The distribution curve obtained clearly shows a minimum at the neutral axis of the bar. Moreover, in the region of the neutral axis, the fractured surface of entirely brittle bars was usually more rough and furrowed than in the tension and compression zones of the bars. This suggests that more energy is absorbed during the propagation of the crystalline crack through the region of the neutral axis, and consequently that the tendency to brittle fracture will be at a minimum at the neutral axis of the specimen.

It was thought that this minimal tendency to start crystalline fracture, which was found to occur

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at the neutral axis of the test bar, would be related to the strain history of the material at the root of the moving crack. This suggestion was supported by the results of local strain measurements, shown in Fig. 5. These measurements were made on a fibrously fracturing test bar provided with a 1-mm. deep notch; the different notch depth is explained by the fact that the early experiments were carried out using 1-mm. notches. Serious objections can hardly be raised to the citing of these experiments, because a minimum in the histogram for ' mm. fibrous ' was also found with 1-mm. notches. Each of the points through which the curves of Fig. 5 were drawn represents the total amount of strain found at a certain distance from the notch, and up to the arrival of the top of the crack. Exceptions are the two points 65 mm. from the notched side of the bar, which represent the strains up to the highest load applied. At this load, however, the top of the crack had not yet reached the 65-mm. line, but had only propagated about 61 mm. from the notched side of the bar. Only absolute values of strain were plotted, and in those cases where an initial compression strain was followed by a tensile strain, the absolute values of both were added as an arbitrary approximation of the combined effect. Load was increased stepwise; after each loading, the bar was taken out of the machine and put under the microscope for strain measurements. To this end, one of the surfaces of the specimen was polished and provided with a rectangular network of scratched lines, 5 mm. apart. Strains were measured on two gauge lengths (10 and 30 mm.), and in the length direction of the bar, perpendicular to the direction of crack propagation. In this experiment, the measurement of strain in the direction of crack propagation was omitted. This means that, especially in the compression zone of the bar, the measured strain will probably be less than the actual strain because the downward compression, caused by the impression of the loading roll, was neglected. Moreover, the strains were measured at the surface of the specimen and on rather macroscopic gauge lengths. They do not pretend to give information about the local deformation in the microscopic region at the root of the crack.

The position of the top of the **V**-shaped crack front in the centre of the plate thickness could not be determined by direct measurement; only the crack length at the surface of the plate could be measured. However, the relation between the crack lengths in the core of the bar and at the surface could be deduced from the shapes of the fibrous-crystalline boundaries in numerous fractured bars, showing crystalline rest fractures started from various fibrous crack lengths. Using this relation, the probable position of the top of the crack at each of the applied loads was estimated.

It was thought that the marked increase of the tendency to start crystalline fracture found in the compression zone of the notched-bend test might be caused principally by the downward compression strain exerted by the loading roll, situated exactly opposite the notch. To test this possibility, the usual three-point loading was compared with four-point loading, using equally distributed test specimens from the same plate. In four-point loading, two pressure rolls were applied, 100 mm. apart, to avoid the possibly disturbing influence of the downward compression opposite the notch. A notch depth of 1 mm. was used in these tests.

From 17 three-point loaded tests, eight specimens started crystalline fracture before the neutral axis (' mm. fibrous ' 1–10, mean value 5). All the other nine specimens started crystalline fracture after the neutral axis (' mm. fibrous ' 41–56, average 47). In 18 four-point loaded tests, only five specimens started before the neutral axis (' mm. fibrous ' 6–17, average 11); the other 13 all started crystalline fracture after the neutral axis (' mm. fibrous ' 35–52, mean value 47).

These results show that an increased tendency to start crystalline fracture occurs in the compression zone of the bar in four-point loading also, since none of the fractures was completely fibrous. On the other hand, the tendency to start crystalline fracture before the neutral axis appears to be lowered by four-point loading. This difference, however, has a statistical significance level of only about 80%. If essential, this difference might be due to the average stress in the cross-section of the bar being a little more tensile in three-point loading. This, however, has not yet been proved.

LOAD-DEFLECTION DIAGRAMS AND SEVERITY LEVELS

In the standard test, which uses a 3-mm. deep notch, each type of steel was found to have a characteristic mean load-deflection curve, the whole course of which was followed by fully fibrous bars. When various bars from the same type of steel but with different degrees of brittleness are tested, they will all follow approximately the same load-deflection curve, and only the length of the curve section that is actually followed up to the point where crystalline fracture starts will be different. However, even when all the tests are made with the same type of steel, some scatter of load-deflection curves will occur, probably caused partly by the fact that the tendencies to start and propagate a fibrous crack are not quite constant, and partly by some scatter of test conditions. The amount of this scatter is shown by Figs. 6*a* and *b*. The test results in these graphs were obtained from a number of test coupons taken from four pairs of plates that had different degrees of brittleness, but made from the same type of steel. For clarity, the results for each pair of almost equally brittle plates are represented in Figs. 6*a* and *b* by means of the same sign. In this way, only four average grades of brittleness were distinguished; the points at which the fracture changed to crystalline are indicated in the diagrams by four different signs.

The values for the depth of the fibrous area under the notch (' mm. fibrous ') at the start of crystalline fracture are represented by solid dots. These graphs confirm that, on the average, the incipient fibrous crack is started at a deflection of about half the deflection at maximum load for fully fibrous fractures.

From the scatter of the values for ' mm. fibrous,' it might be concluded that fully crystalline fractures sometimes occur at a deflection as large as 6·5 mm. Errors may, however, be made in judging whether a fracture is fully crystalline or not. In some cases, an

incipient crack was observed which had travelled in the length direction of the bar, and then, while turning its plane of propagation through an angle of 90°, had changed to crystalline. Incipient fibrous cracks of this kind are difficult to observe, especially when looking perpendicular to the final plane of fracture. This is one of the reasons why the deflection was chosen as a better criterion in this part of the diagram.

In the standard test, using a 3-mm. notch, the tendency to brittle fracture of the steel undergoes three successive examinations of increasing severity, taking place respectively at the root of the notch, in the tension zone, and in the compression zone of the specimen, as was proved by the experiments already described. The high severity in the compression zone is possibly related to the reversing character of the deformation in that part of the specimen.

In regard to the differences between the three severity levels (*see* Fig. 4 of the previous paper[1]), some tentative conclusions can be deduced from the experiments represented in Figs. 6*a* and *b*. At + 20° C., the bulk of the tests from the two best plates showed fully fibrous fractures (quality of bars above severity level of compression zone). At 0° C., however, all tests from these plates started crystalline fracture after the neutral axis (quality of bars between severity levels of tension and compression zones). This means that the differences

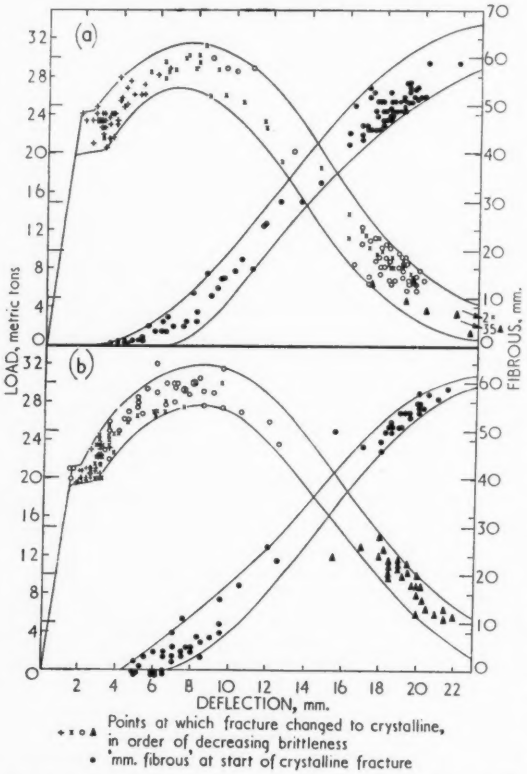
(a)
(b)
LOAD, metric tons
FIBROUS, mm.
DEFLECTION, mm.
Points at which fracture changed to crystalline, in order of decreasing brittleness
'mm. fibrous' at start of crystalline fracture

Fig. 6—Load-deflection diagrams for 1-in. plates of four different grades of brittleness (notch depth 3 mm.): (*a*) + 20° C.; (*b*) 0° C.

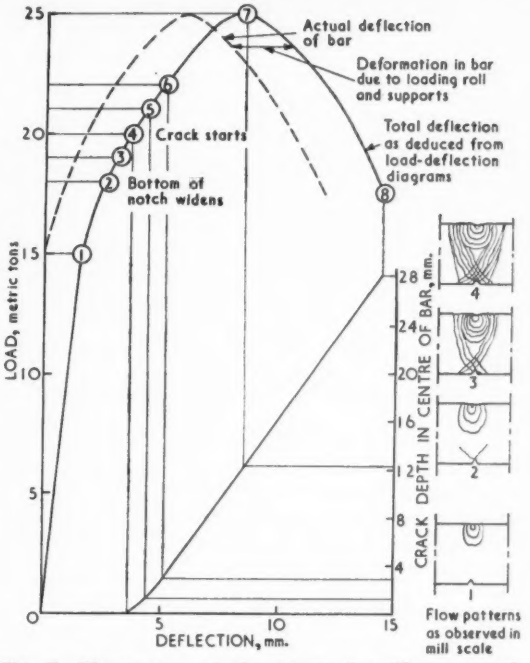
Actual deflection of bar
Deformation in bar due to loading roll and supports
Total deflection as deduced from load-deflection diagrams
Crack starts
Bottom of notch widens
LOAD, metric tons
DEFLECTION, mm.
CRACK DEPTH IN CENTRE OF BAR, mm.
Flow patterns as observed in mill scale

Fig. 7—Phenomena at the start of a fibrous crack (notch depth 3 mm.)

between the severity levels of the tension and the compression zones will be about 20° C., or somewhat more (expressed in the scale of transition temperatures), and suggests that the scatter of test results from the plate sections tested is somewhat less. Most of the bars from the second-best pair of plates were found to start crystalline fracture after the neutral axis, when tested at + 20° C. Only five out of 40 bars started crystalline fracture before the neutral axis and after the maximum load had been passed. When tested at 0° C., all the bars from these plates started crystalline fracture before the neutral axis. Seventeen of these 38 bars started crystalline fracture at the root of the notch, without showing an observable incipient fibrous crack. This would mean that, for this type of steel, the difference between the severity levels of notch root and tension zone will be 10° C., or somewhat more. This is confirmed by the tests from the second-worst pair of plates. At + 20° C., 50% of these tests started crystalline fractures before the neutral axis, whereas only one showed a fully crystalline fracture.

The occurrence of the third examination in the compression zone has some advantages, especially when testing is done at only one testing temperature. When, for instance, all tests from a plate section are found to have fully fibrous fractures, the fracture-appearance transition temperature will be more than about 30° C. lower than the testing temperature used. When all tests are found to start crystalline fracture after the neutral axis, it may be assumed that the appearance transition temperature will be about 10° C. lower than the testing temperature.

The difference between the severity levels of the notch and the fibrous crack in the tension zone was

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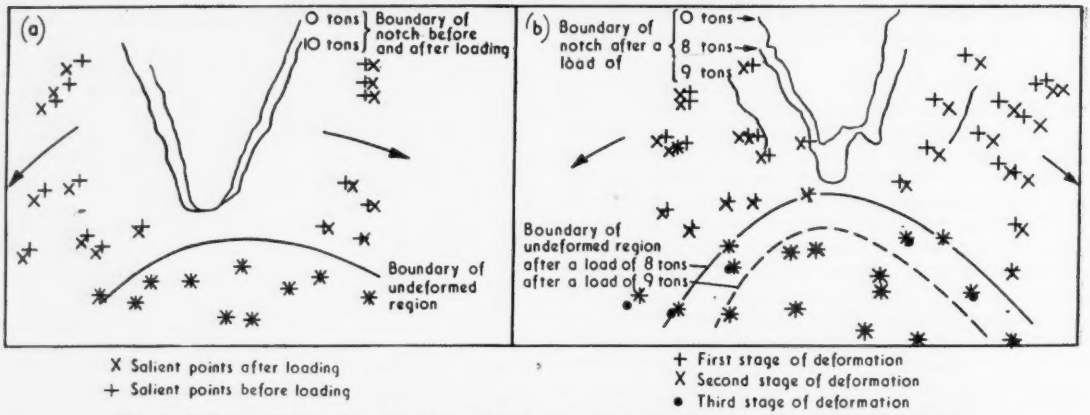
(a)
0 tons
10 tons
Boundary of notch before and after loading
Boundary of undeformed region
(b)
Boundary of notch after a load of
0 tons
8 tons
9 tons
Boundary of undeformed region after a load of 8 tons
after a load of 9 tons
X Salient points after loading
+ Salient points before loading
+ First stage of deformation
X Second stage of deformation
• Third stage of deformation

Fig. 8—Deformation at the root of a notch 8 mm. deep, during the early stages of loading

found to vary from steel to steel, as was deduced from the variation of the difference Δ between the fracture-appearance transition temperature T_2 and the ductility transition temperature T_1.* This quantity Δ was found to vary between about 5° and 25° C., the standard deviation being 6·5° C. A statistical analysis showed that Δ was correlated with the plate thickness t and the appearance transition temperature T_2, according to the regression equation

$$\Delta - 12 = 0{\cdot}42(t - 31) + 0{\cdot}10(T_2 - 16).$$

The correlation coefficients were 0·77 and 0·51 respectively, which means that the significances of both correlations were at least 99%. Obviously, the severity of the natural crack decreases more than that of the notch when the plate thickness is lowered. Using this equation, the residual standard deviation of Δ was 3·9° C. There is evidence that this residual scatter is due to the influence of the type of steel and the type of microstructure on the value of Δ. Analogous phenomena were found by Bagsar.[3]

PHENOMENA AT THE ROOT OF THE NOTCH

To learn more about the conditions needed to start a fibrous crack from the root of the notch, a series of tests was made using eight neighbouring bars from the same 1-in. thick plate. Tests were carried out at room temperature, and a plate was chosen that had a fracture-appearance transition temperature of − 10° C.; a notch depth of 3 mm. was used. Each of the bars was loaded up to one of a series of different loads. At the same time, the flow patterns that occurred in the mill scale of the specimen were observed. After loading, the bars were taken out of the bending jig, and then, starting from only one of the surfaces, the bar was machined to half-thickness to observe the occurrence of a crack at the root of the notch and in the centre of the plate thickness. The results of these observations are shown in Fig. 7.

It was found that at a load of 15 tons (case 1) the whole deflection as measured on the diagram had to be attributed to the local impressions of loading roll and supports in the specimen. At this load, a considerable region under the loading roll had yielded, as was shown by the flow pattern in the mill scale. At a load of 18 tons (case 2), which was slightly higher than the yield load of the diagram, the bottom of the notch had widened, and two flow lines originating from the apex of the notch were observed. Thus, the yield load of the diagram, the widening of the notch bottom, and the appearance of the two flow lines seem to be inter-related. A crack did not start until a load of 20 tons (case 4) was applied. Before this, at a load of 19 tons (case 3), the two flow regions had joined, and flow lines were observed running across the whole width of the specimen.

In another investigation, an attempt was made to get some information about the deformation under the notch during the early stages of loading. To this end, one of the surfaces of the specimen was polished and etched in the neighbourhood of the notch, so that the microstructure could be observed. Bars were loaded stepwise and, after each loading, the specimen was put under the microscope for the microstructure under the notch to be photographed at a magnification of 200. These photographs then were projected on the same sheet of paper by pricking with a needle through the salient points of the photograph, such as distinct intersections of grain boundaries, inclusions, etc. The relative displacements of these salient points furnished information about the deformation under the notch.

Three experiments were made in this way, using specimens from three different types of steel, with notches 8 mm. deep. In one of these bars, a brittle fracture was obtained; the deformation observed before fracture under the notch of this specimen is shown in Fig. 8*a*. The two parts of material on either side of the notch appear to move in opposite directions by shearing over a rather distinct cylindrical shear plane, which at the same time forms the boundary of an undeformed region under the root of the notch. Any brittle fracture might be expected to start in the undeformed region under the notch before the start of shear fractures along the cylindrical shear plane, but this could not yet be proved. Observed macroscopically, some vague indications of

* The definitions and the procedures for the determination of the transition temperatures are described in the previous paper[1]: T_2 is the temperature at which the average value of ' mm. fibrous ' is 32, and T_1 is the temperature at which the deflection at maximum load is half-way between the extremes.

Table I

CHARPY V-NOTCH AND SLOW-BEND TRANSITION TEMPERATURES FOR 7 PLATES OF DIFFERENT GRADES OF BRITTLENESS

Plate	Symbol in Figs. 10–13	Thickness, mm.	Slow-Bend Transition Temperature (32 mm. fibrous), °C.	Charpy V-Notch Transition Temperature	
				4 kg.m./sq. cm.	50% Fibrous
A	×	19	+29	+25	+44
B	○	25	+35	+35	+53
C	●	25	− 7	+13	+18
D	△	38	+44	+25	+52
E	▲	38	− 3	+ 3	+19
F	▽	38	−37	−17	−12
G	▼	40	−13	−31	− 2

incipient shear fractures were found at the notch of the brittle specimen. This would point to the possibility of brittle fracture starting from a small incipient shear crack, the plane of propagation of which is bent downwards immediately after its birth. The observations were made, however, on the surface of the specimen; conditions may be different in the centre of the bar. The observations on fibrous bars showed the same type of deformation under the notch; one of these observations is shown in Fig. 8*b*. In the last stage, two incipient shear cracks had formed, and only the neighbourhood of the undeformed region could be observed microscopically. Results show that the cylindrical boundary of this region appears to move downward. Observed macroscopically, the specimen showed two distinct shear cracks, propagating at an angle of about 45° to the direction of loading.

DISCUSSION OF CRITERIA

It was pointed out in the previous paper[1] that the criterion of total energy to fracture would be of questionable value, because it consists of two parts, *i.e.*, the work absorbed up to the start of a fibrous incipient crack, and the work absorbed during the propagation of the fracture (fibrous or crystalline). Thus, the tendency to start and propagate fibrous cracks and the tendency to the crystalline mode of crack propagation are both involved. According to

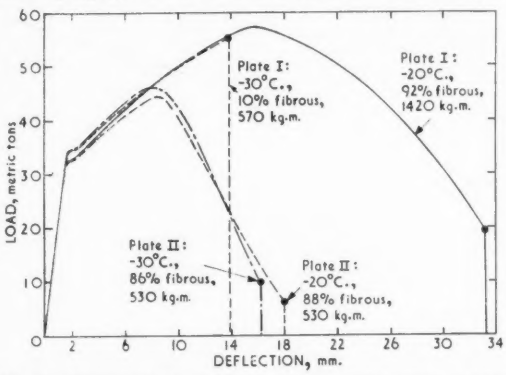

Fig. 9—Comparison of two 1·5-in. mild-steel plates, showing lack of correlation between fracture appearance and total energy to fracture (notch depths 3 mm.)

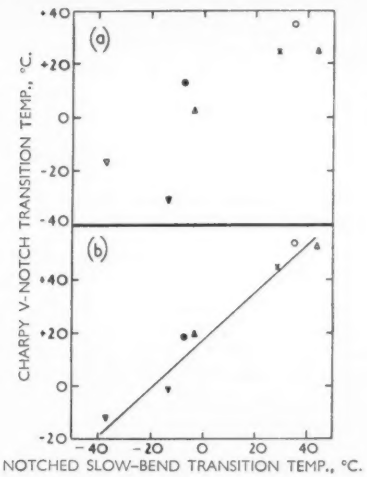

Fig. 10—Comparison of Charpy V-notch and notched slow-bend transition temperatures, Criterion for notched slow-bend test, 32 mm. fibrous; criteria for Charpy test, (*a*) 4 kg.m./sq. cm. and (*b*) 50% fibrous

the authors' experience, these two tendencies are not related to each other in a simple way.

An example of this is shown in Fig. 9, in which the load-deflection diagrams of two different plates are compared. Both plates were 1·5 in. thick, and had approximately the same tensile strength. The test results at − 20° C. show that the plates are very different in regard to the energy required for fibrous fracture. The plate with the higher energy absorption (plate I), however, was found to show a greater tendency to crystalline crack propagation. This will be seen from the test results at − 30° C., which show that plate I has only 10% fibrous, whereas plate II shows a fracture that is 86% fibrous. However, in spite of this difference, plate I absorbs a little more energy than the far more fibrous plate II. The same paradoxical results were often found with impact values.[1]

Consequently, a classification of plates according to brittleness may give erratic results when an impact energy figure is used as a criterion. This is shown by Fig. 10*a*, in which the transition temperatures of various plates listed in Table I, determined with the Charpy V-notch test and using 4 kg.m./sq. cm. as a criterion, are compared with the fracture-appearance transition temperatures determined by means of the notched slow-bend test. On the other hand, Fig. 10*b* shows that a better correlation is obtained when fracture appearance is chosen as a criterion in the impact test as well. The values for percentage crystalline in this case were determined by eye and by only one person. Generally, however, the estimation of percentage crystalline in the impact test will give rise to great inaccuracy and will not be free from personal errors.

This evidence stresses the desirability of choosing a test in which the various criteria can be determined separately, and would seem to justify the procedure used in the notched slow-bend test, according to which the evaluation of brittleness is based primarily on

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Table II

CHANCE TO 'FIBROUS' FRACTURE IN 3 SLOW-BEND TESTS AS A FUNCTION OF p

Case	I	II	III	IV
Fibrous	0	1	2	3
Brittle	3	2	1	0
Chance	$(1-p)^3$	$3p(1-p)^2$	$3p^2(1-p)$	p^3

types of diagrams and fractures, and not on absolute values of certain criteria.

CHARPY V-NOTCH AND NOTCHED SLOW-BEND TESTS AS ACCEPTANCE TESTS

In this comparison, the objections to the use of impact energy as a criterion for brittle fracture are temporarily neglected, and attention is focused on the relation between the number of tests and the statistical reliability of the average test result alone.

The investigation was based on a large number of test data, obtained from plates for which the transition curves had been determined with both testing methods. The transition temperatures found are given in Fig. 10 and Table I. All test bars were taken perpendicular to the direction of rolling. The original position of the Charpy bars was immediately below one of the plate surfaces.

The test results of all the plates tested were collected in one graph by plotting the test data of each plate against the difference δ between the testing temperature and the transition temperature of that particular plate. Thus, the absolute values of the different transition temperatures were eliminated and the various transition curves were, as it were, shifted so as to cover each other. For the Charpy V-notch tests, a plot of impact energies was made according to this procedure (*see* Fig. 11). The transition temperature was defined as the testing temperature at which the average impact energy was 4 kg.m./sq. cm. In the range of δ between $-25°$ and $+50°$ C., the regression line was computed, and is shown in Fig. 11. The regression coefficient was found to be 0·073 kg.m./sq. cm./° C. The residual standard deviation of the data from this line, computed for the range of δ between $-20°$ and $+20°$ C., amounted to 0·7 kg.m./sq. cm.

Table III

RELIABILITY INTERVAL AS A FUNCTION OF THE NUMBER OF SLOW-BEND TESTS AND FOR THE ACCEPTANCE REQUIREMENT 'PREDOMINANTLY FIBROUS'

Number of Tests	p	$(1-p)$	Reliability Interval, °C.
1	0·95	0·05	11
3	0·867	0·133	8·8
5	0·810	0·190	7·2
7	0·775	0·225	6·6
9	0·750	0·250	6·0

The consequences of this in relation to quality control by impact tests may be illustrated by the following example: suppose that the steelmaker and the consumer have agreed upon doing one impact test per plate at only one testing temperature, say $-10°$ C., and that an acceptance figure of 4 kg.m./sq. cm. is chosen. Then, when an impact energy of 4 kg.m./sq. cm. is found, the plate is to be accepted. In this case, however, using a significance level of 95%, the true average impact energy of this plate may be $1·65 \times 0·7 = 1·16$ kg.m./sq. cm. lower than 4 kg.m./sq. cm.

From this it follows, using this regression coefficient, that the consumer must reckon with the possibility that the transition temperature of the plate may be 16° C. higher than the testing temperature. The steelmaker, on the other hand, to limit the percentage of rejections to a maximum of 5%, will be compelled to offer plates that have an average impact energy 1·16 kg.m./sq. cm. higher than the acceptance figure, which means a transition temperature that is 16° C. lower than the testing temperature. In this case, the total width of the reliability interval is 32° C. It is obvious that the adequacy of quality inspection can be increased by narrowing the gap between the steel-

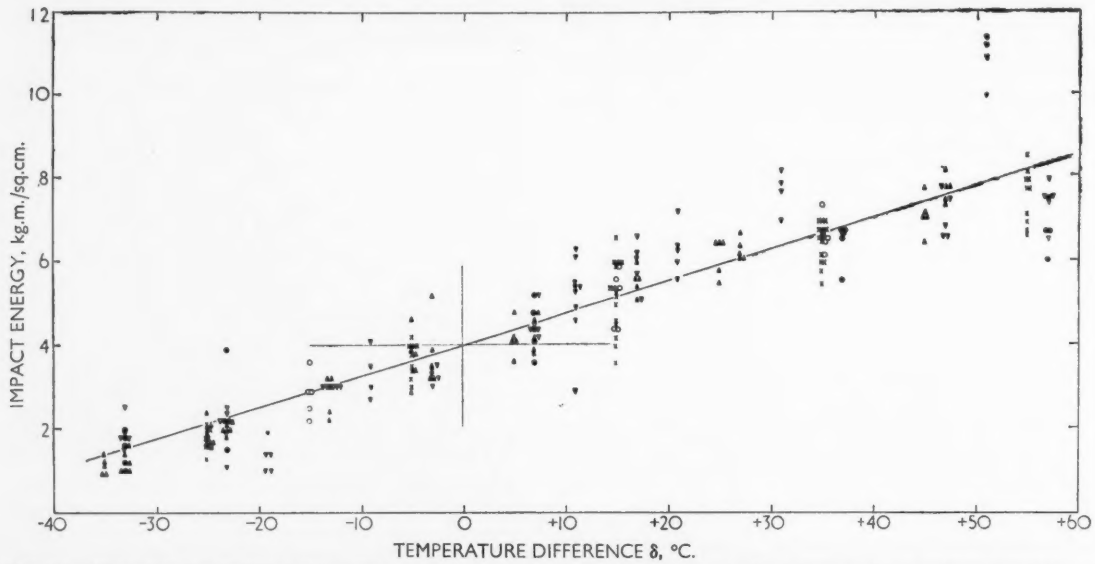

Fig. 11—Charpy V-notch impact energy as a function of δ (plates *A* to *G*); δ = testing temperature minus transition temperature. Criterion for transition temperature = 4 kg.m./sq. cm.

maker's target and the consumer's certainty limit. When more tests per plate are made, and the average impact energy is chosen as a measure, this gap will be narrowed by a factor equal to the square root of the number of tests. Thus, when five tests per plate are taken, the reliability interval will be 14·5° C.

For the notched slow-bend tests, the usual criterion ' mm. fibrous ' was plotted as a function of δ (*see* Fig. 12). In this test, in contrast with the impact test, the transition has a more discontinuous character, and the distribution of ' mm. fibrous ' has two maxima, on both sides of the neutral axis. Consequently, the scatter of ' mm. fibrous ' is very inconstant as a function of δ, high values being confined to the transition region. This makes the criterion ' mm. fibrous ' inaccessible to statistical analysis. Thus, for this purpose, a more simple ' yes or no ' criterion was chosen, distinguishing between only two cases, *i.e.*, the start of crystalline fracture before or after the neutral axis of the specimen; for the sake of simplicity, these two cases will be called ' brittle ' and ' fibrous ' respectively. From the data of Fig. 12 the regression line of the chance to ' fibrous ' fracture was produced (*see* Fig. 13), denoted by p as a function of δ. It will be seen that p increases almost linearly from 0 to 1 in the interval of δ between $-6°$ and $+6°$ C. Suppose that the steelmaker and the consumer have agreed upon making one bend test per plate at only one testing temperature, and that for acceptance of the plate a 'fibrous' fracture is required. Then, when a ' fibrous ' test result is obtained, the plate is to be accepted. In this case, however, using a statistical significance level of 95%, the true value of p may have been only 0·05. Thus, using the regression line for p, the consumer must reckon with the possibility that the transition temperature of the accepted plate may be 5·5° C. higher than the testing temperature. The steelmaker, on the other hand, to limit the percentage of rejections to a maximum of 5%, will be compelled to offer plates for which $p = 0·95$ or more, corresponding with a transition temperature that is 5·5° C. lower than the testing temperature. Thus, for one test per plate, the total width of the reliability interval is 11° C., which is far better than the corresponding value for one impact test (32° C.)

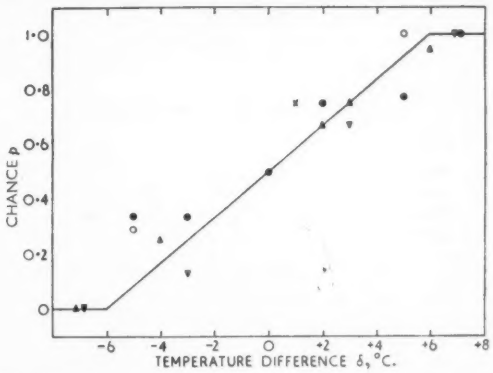

Fig. 13—Chance to fibrous fracture p up to beyond neutral axis as a function of δ (derived from Fig. 12)

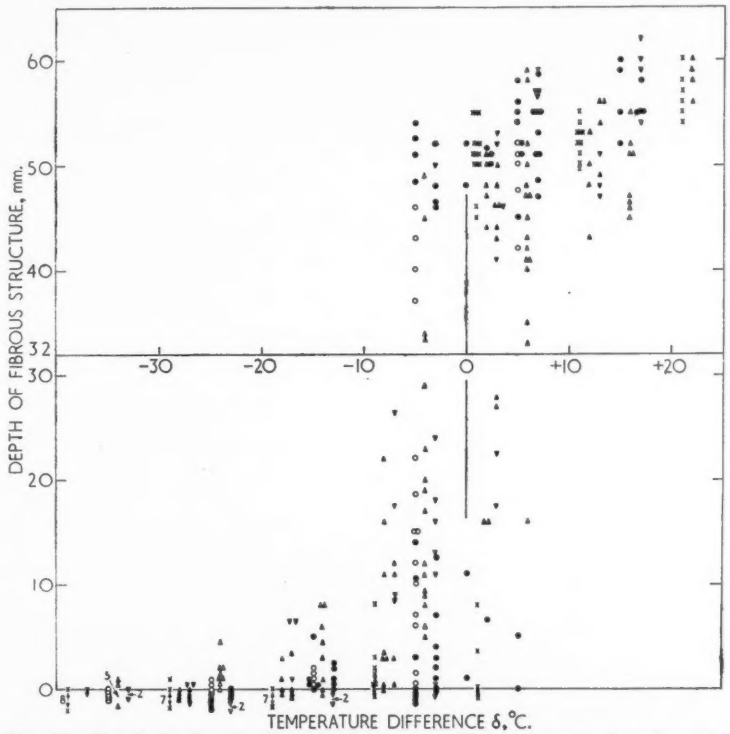

Fig. 12—Notched slow-bend criterion ' mm. fibrous ' as a function of δ (plates *A* to *G*); δ = testing temperature minus transition temperature. Criterion for transition temperature = 32 mm. fibrous

When three tests are made, four cases may occur, which are listed in Table II.

The chances for each of these cases are found by development of the expression $[(1 - p) - p]^3$. Suppose that the plate is to be accepted when the test result is predominantly fibrous (case III or IV). Then, using a significance level of 95%, the reliability interval can be determined by resolving the equation $3p^2(1 - p) + p^3 = 0·95$, which yields $p = 0·867$ and $(1 - p) = 0·133$. This means, using the regression line of p, that the reliability interval extends from $\delta = -4·4°$ C. to $\delta = +4·4°$ C.: total width 8·8° C. Analogous computations, also based on the criterion of ' predominantly fibrous,' were made for 5, 7, and 9 tests per plate. The results are summarized in Table III.

When five bars are tested, the requirement of ' predominantly fibrous ' would mean that the plate is to be accepted when at least three bars show

Table IV

RELIABILITY INTERVAL AS A FUNCTION OF THE ACCEPTANCE REQUIREMENT FOR 5 SLOW-BEND TESTS

Acceptance Requirement	Limits of Reliability Interval, °C.	
3 fibrous 2 brittle	−3·6	+3·6
4 fibrous 1 brittle	−5·0	+1·9
5 fibrous 0 brittle	−5·8	−0·5

'fibrous' fractures. The severity of the acceptance criterion, however, may be increased to four, or finally to five, 'fibrous' bars. The influence of this on the reliability interval is shown in Table IV.

It may be concluded that the reliability intervals obtained with the impact test for equal numbers of test bars are more than twice as wide as those obtained with the notched slow-bend test.

The pattern of notched slow-bend specimens did, however, cover an appreciable length of each plate. The tested region usually extended between the limits of 15 or 20% from the top end and 15 or 20% from the bottom end of the plate. The impact tests, however, had been taken from relatively small areas, mostly narrow strips across the width of the plate, and usually located at a distance of 15 or 20% from the top end. Only in one case (plate *A*) were both a top and a bottom strip tested. Because of this, a still greater difference between both testing methods would probably have been found if the impact tests had also been distributed over an appreciable length of the plate. Moreover, it is to be expected that the reliability interval of the notched bend test will be decreased by using 'mm. fibrous' as a criterion instead of the 'yes or no' criterion used in the statistical analysis, since the actual amount of 'mm. fibrous' gives additional information about the location of the transition temperature.

A further disadvantage of the impact test is that the slopes of the regression lines for impact energy may be different for different steels. Figure 11 shows that the individual regression of plate *G* is steeper than that of the other plates. In the notched-bend test, however, using 'mm. fibrous' as a criterion, no such discrepancy was encountered. Figure 12 shows that the data for plate *G* fit in well with those from the other plates.

Acknowledgments

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HISTORICAL NOTE NO. 31

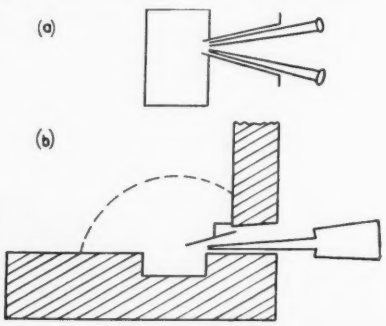
An 18th Century Bloomery at Garstang, Lancs.

By Dr. H. R. Schubert

In the course of the sixteenth and eighteenth centuries the blast-furnace producing highly carburized pig iron, which was converted into malleable iron by an elaborate process of refining and hammering in the forge, gradually found its way all over the British Isles. Nevertheless the older and more primitive process of producing malleable iron directly from its ores in bloomeries or bloomsmithies was not completely superseded by the new process. It was still practised at places where a comparatively pure ore suitable for the bloomery process was obtainable. Such a bloomery was operated in the eighteenth century at Garstang, between Preston and Lancaster on the ancient road to Scotland.

Little is known of the existence of this bloomery apart from a brief remark in Bishop Dr. Pococke's travel diary.[1] Passing through Garstang in 1756 he observed "*the smoke of some smelting-houses, which are erected there.*" The bloomery at Garstang was apparently still operated in the late eighteenth century, for two diagrams of the hearth are preserved in a manuscript written about 1780.[2]

Diagram *a* is a ground plan of the "fire-place," *i.e.*, the rectangular cavity in which smelting was conducted; *b* shows a section of the front of the bloomery The



small size of the fireplace and the position of the bellows, more towards the place where the worker stood, exhibit a striking resemblance to the contemporary English finery hearth.

[1] The Travels through England of Dr. Richard Pococke, edited by J. J. Cartwright, vol. I, p. 13, London, 1888. (Camden Society New Series vol. XLII.)

[2] Cardiff Central Library, MS. 3250, vol. IV, facing p. 76; the latest dated entry in the manuscript is 1779.

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Thermal Stabilization of Austenite in Carburizing Steels

By
H. M. Otte and T. Ko

SYNOPSIS

A study has been made of the retained austenite in two carburized steels. Ageing at room temperature causes stabilization of austenite in a carburized Krupp steel, but the effect can be removed by sufficient further cooling. 711

When austenite of a given chemical composition is cooled to a fixed reference temperature below M_s at a rate sufficient to give martensitic structure, the degree of transformation often depends on the rate of quenching. The amount of retained austenite increases with decreasing cooling rate.[1] It has recently been shown[2] that, in Fe–C–Ni alloys containing about 1% of carbon, the difference is due to an effect occurring during quenching in the temperature range 300–400° C., which lowers the M_s and reduces the amount of martensite formed at a given reference temperature. It was also observed that the amount of martensite formed below M_s is affected by isothermal holding above and below M_s. These effects are known as thermal stabilization of austenite.

Isothermal stabilization of austenite has been previously observed in high-chromium, high-carbon steels above M_s,[3] and also in other steels below M_s.[4–8] Ko and Morgan[2] have shown, however, that stabilization, being an activated process, is slow at temperatures below 200° C. in nickel steels and that stabilization below this temperature contributes little towards the increase in retained austenite during normal quenching.

Isothermal stabilization at room temperature can be important, however, if the steel is to be refrigerated to remove the residual austenite, as the time of holding before subzero quenching may be long, and the rate of stabilization is greatly increased in the presence of martensite.[2, 7] The effect is more significant in alloy steels, in which considerable amounts of austenite may be present at room temperature, and the rate of stabilization may be high in the presence of chromium[3, 9] and probably also of other carbide-forming elements.

In the present work the effects of stabilization during quenching on the amount of retained austenite have been investigated in two carburized steels, and in one of them isothermal stabilization at room temperature has also been studied. Retained austenite is often present in a carburized alloy steel. For example, Troiano and DeMoss[10] have observed that some austenite is present in a carburized Krupp steel quenched from 800° C. Recent work[11] in this Department has shown that the very small amount of retained austenite present in a carburized Krupp steel, heat-treated by normal practice, can cause a significant lowering of the static load that the case-hardened material can carry.

EXPERIMENTAL PROCEDURE

Specimens from a carburized steel were austenitized at 1100° C. in a salt bath for a period sufficiently short to preserve the carbon gradient and yet long enough to allow all the carbide to dissolve. After cooling to some desired temperature, the retained austenite gradient from the surface inwards was measured microscopically. The carbon gradient was determined by chemical analysis, using different specimens.

Preparation of Materials

The two steels used had the following compositions:

	Krupp Steel	Nickel Steel
C, %	0·12	0·18
Ni, %	3·80	4·89
Cr, %	1·24	0·32
Mo, %	0·07	0·29
Mn, %	0·40	0·41
Si, %	0·22	0·21
S, %	0·018	0·013
P, %	0·017	0·014

Rolled bars, approximately 1·4 in. dia., were machined to 1 in. square or 1 in. dia. The nickel steel was pack-carburized in a commercial compound, and the Krupp steel was gas-carburized with cracked town-gas to which 2·8% of butane had been added. The square bars were cut into $\frac{3}{16}$-in. slices, which were halved and heat-treated as required in a suitable high-temperature salt bath. The standard size of carburized specimens was thus 1 in. × $\frac{1}{2}$ in. × $\frac{3}{16}$ in., and the face exposed on halving was the one generally examined.

The round bars were machined to obtain samples for chemical analysis.

Measurement of Carbon Penetration

After tempering the carburized bars sufficiently to be machinable, cuts were made initially 0·005 in. deep and then, after the first five cuts, 0·010 in. deep. The accuracy of one cut was within ± 0·001 in.

The carbon content of the turnings obtained from each cut was determined chemically, with an accuracy of about ± 0·02%. The analyses reported represent the average carbon content for the depth of the cut.

A comparison of the carbon penetration curves determined from a round and a square bar carburized simultaneously showed no measurable difference in the average carbon contents at various depths. In the square bar, cuts were taken only down the middle of each face, over a $\frac{1}{2}$-in. width. It was thus permissible to compare results obtained from square bars with a carbon penetration curve obtained from a round bar treated at the same time, thereby avoiding the difficulty and tediousness of machining square bars.

Measurement of Retained Austenite

After 0·020 in. had been removed from the surface

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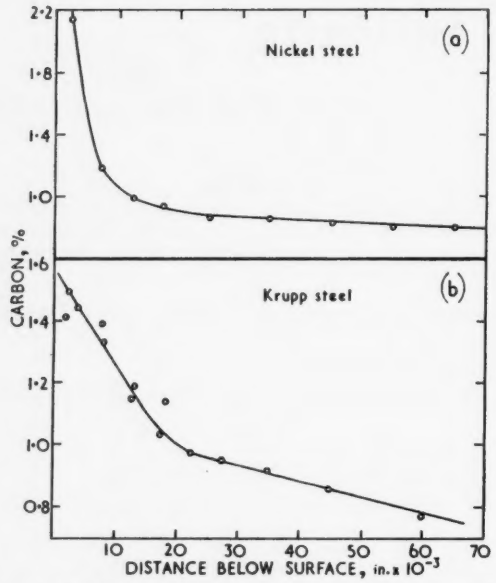


Fig. 1—Carbon penetration curves: (*a*) Nickel steel; (*b*) Krupp steel

by grinding under water, the amount of retained austenite was measured by microscopical counting, using a tempered and etched specimen. Tempering for 1 min. at 300–350° C. increased the contrast between the austenite and the martensite considerably after etching with 4% nital containing 1% 'zepharin' chloride[12] (cetyl dimethyl benzyl ammonium chloride). The counting was made by linear analysis at a magnification of × 1500 along lines engraved parallel to the carburized surface. These represent lines of constant carbon content. Taking into consideration the nature of the work and the reproducibility between different specimens, which generally fell within ± 2·5%, the number of counts made in each set was fixed so that the results, at their worst, gave an accuracy with 65% probability that the error was less than ± 2·5%, or 95% probability that the error was less than ± 5%, assuming a normal distribution. The accuracy was generally higher, owing to the use of duplicate specimens.

The variation of retained austenite with depth was determined at both ends of the polished surface of the specimen, thus giving two sets of values. If a duplicate specimen was also measured, four sets of points were obtained. Different symbols used on each curve when plotting the results (Figs. 5 and 7) indicate, unless otherwise specified, results from the different sets, so as to show the general reproducibility and the accuracy.

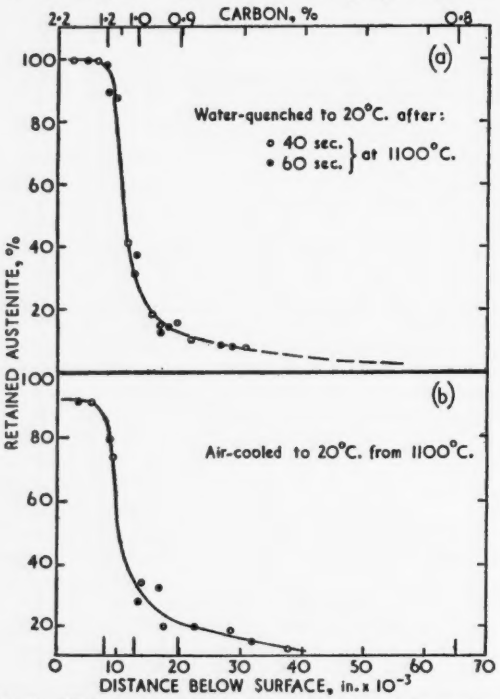


Fig. 2—Nickel steel: Retained austenite (*a*) in water-quenched specimens, (*b*) in air-cooled specimens

RESULTS

Carbon and Retained Austenite Gradients

The carbon penetration curve for the nickel steel, pack-carburized for 1 week at 900° C. followed by 1 week at 800° C., is shown in Fig. 1*a*. The high carbon content (above 2·2%) at the surface was due to the formation of carbides made possible by the chromium and molybdenum contents of the steel and the low carburizing temperature (800° C.). The initial carburization at 900° C. produced a surface containing 1·1% of carbon and was required to prevent the carbon gradient from being too steep. The carbon penetration curve of the Krupp steel, gas-carburized for 24 hr. at 900° C. followed by 15 hr. diffusion in a neutral atmosphere, is shown in Fig. 1*b*.

Since the carbon penetration curves of the carburized specimens could be determined only at a stage before the final austenitizing treatment, this had to be such as to preserve the carbon gradient as far as possible. An austenitizing temperature of 1100° C., using a salt bath, was the most convenient and was used throughout the investigation. Direct measurements showed that, after immersion in the salt bath, the specimens attained this temperature

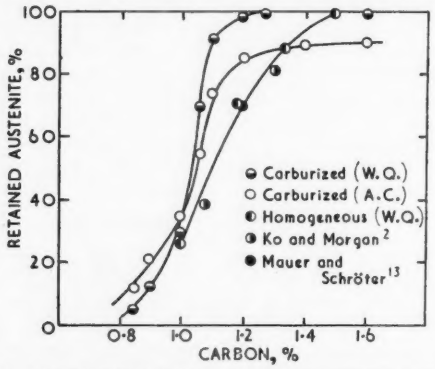


Fig. 3—Nickel steel: Effect of carbon content on the amount of retained austenite

within 30 sec. Immersion for 40–60 sec. did not alter the carbon gradient sufficiently to affect the retained austenite curve, shown in Fig. 2*a* for the nickel steel water-quenched from 1100° C., and in Fig. 2*b* after air-cooling to room temperature (20° C.).

The effects of carbon on the amount of austenite retained at 20° C. in the nickel steel after water-quenching and air-cooling are shown in Fig. 3. Above 1% of carbon, carbide precipitation occurred during air-cooling, causing greater transformation of austenite. In the low-carbon region, air-cooled specimens retained more austenite than the water-quenched specimens.

These results are compared also in Fig. 3 with the austenite contents in homogeneous specimens of the same steel, obtained by carburizing sections $\frac{3}{16}$ in. thick for various periods and then homogenizing in charcoal at various temperatures between 900° and 1100° C. until homogeneity was found to be satisfactory by microscopic examination. Specimens containing 1·5% of carbon were not sufficiently homogeneous, and the result, although given on the curve, cannot be taken as entirely reliable. The agreement between the present results and those obtained by other workers[2, 13] was good. There is an indication that more austenite is retained in the carburized steel at a given carbon level than in the homogeneous one of the same carbon content. The difference is fairly large above 1·1% of carbon.

The possible existence of the effect of a systematic variation of carbon concentration, or composition in general, on the transformation of austenite to martensite can have considerable significance. The present observations, although not conclusive because of the low overall accuracy of the curve for the carburized steel, are consistent with the results of Rowland and Lyle[14] (who reported a lower M_s for carburized specimens compared with homogeneous ones of corresponding equivalent carbon content, in the range 0·4–0·7% of carbon), although they suggested alternative explanations.

Since the M_s temperature and the carbon content are interdependent variables, it might be expected that a temperature gradient would have the same effect as a carbon gradient. The effect of a temperature gradient has been observed[15] in a single crystal of 30% Ni–Fe alloy. By holding one end of the crystal above M_s, the other end could be cooled well below M_s without transformation occurring.

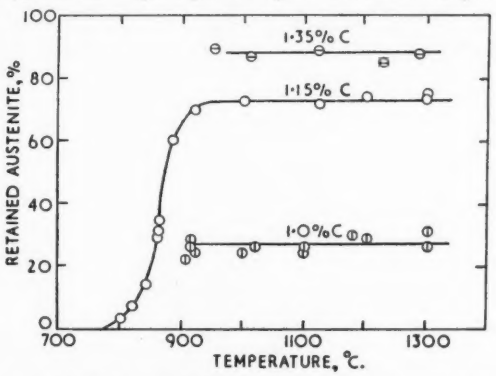
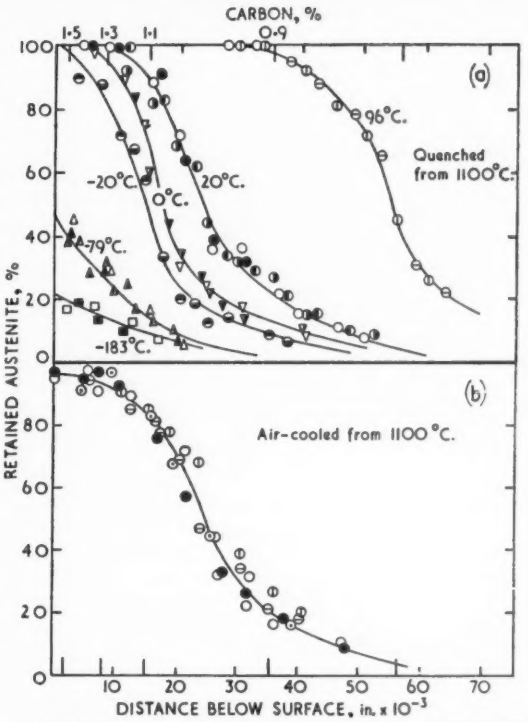


Fig. 4—Nickel steel: Effect of austenitizing temperature on the amount of retained austenite



Quenching Media: 96°, 20°, water; 0°, ice and water; − 20°, ice and brine; − 79°, water, then solid CO_2 and ether; − 183°, water, then liquid oxygen

Fig. 5—Krupp steel: Retained austenite gradient (*a*) at different temperatures, (*b*) after air-cooling to 20° C.

The effect of austenitizing temperature on the amount of retained austenite was also investigated using the homogeneous specimens. These were austenitized in argon (in a furnace described elsewhere[16]) and quenched into water at 20° C. The results (± 3·5%) are given in Fig. 4. There is no indication that the amount of the retained austenite in these nickel steels was affected by the temperature within the austenitic range, as has been found in a 1·1% C, 5·4% Ni steel.[7]

The variation of retained austenite with depth in the Krupp steel, after water-quenching to different temperatures and after air-cooling to 20° C. from 1100° C., is shown in Figs. 5*a* and *b*, respectively. The results have been replotted in Fig. 6. In the low-carbon region there is little difference in austenite between the air-cooled and the water-quenched specimens. In the regions containing more than 1% of carbon, carbide precipitation was visible in the air-cooled specimens.

The reversal of the effect of cooling rate above a certain carbon content, when the critical cooling rate becomes higher than the lowest cooling rate used, has been previously observed[17] in homogeneous plain carbon steels. In a 1·3% plain carbon steel, water- and oil-quenching retained the same amount of austenite (26%) at room temperature. Above 1·3% of carbon more austenite was retained by water-

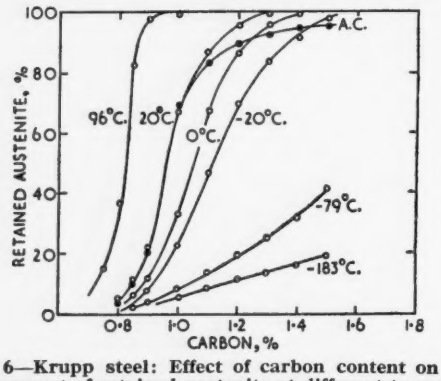


Fig. 6—Krupp steel: Effect of carbon content on the amount of retained austenite at different temperatures (for quenching media *see* Fig. 5)

quenching, and below 1·3% more was retained by oil-quenching.

Isothermal Stabilization of Austenite in Krupp Steel

The amount of austenite retained at various depths in the Krupp steel cooled to temperatures between 96° and — 183° C. is shown in Fig. 5*a*. Holding for up to 8 hr. at 96° C. before cooling the specimen to room temperature produced a gradient of austenite as given in Fig. 7*a*. Comparison of this curve with that obtained by direct quenching to room temperature (Fig. 5*a*) indicated little difference. However, the amount of stabilization observed depends on the reference temperature at which the retained austenite is measured. There was an appreciable difference when the amounts of austenite were compared at 70° C. instead of at 20° C. Similarly, holding the specimens at 20° C. for up to 10 days before further cooling (Fig. 7*b*) had no effect when the specimens were examined for martensite content at — 79° C. By cooling only a few degrees, however, after ageing, stabilization could be detected near room temperature. Thus, after holding for 22½ hr., no transformation occurred on cooling by 20° to 0° C. A further lowering of 20° C. initiated transformation, but the total amount of martensite formed was less than if a direct quench had been used.

The effect of ageing the Krupp steel for 22½ hr. at room temperature at different carbon contents, estimated from the curves, is as follows:

Reference Temp., °C.	Retained Austenite, % Direct Quench	Aged at 20° C.	Difference
1·3% Carbon			
—20	84	93	9
—79	26	26	0
1·0% Carbon			
0	33	67	34
—20	23	46	23
—79	10	10	0
0·9% Carbon			
0	12	21	9
—20	8	14	6
—79	4	4	0

These results show that any stabilization induced in the austenite by holding at a certain temperature is gradually removed if the temperature is sufficiently lowered, until no difference can be detected between the stabilized and the unstabilized austenite; *i.e.*, the transformation of the austenite, once resumed, seems to catch up gradually with the unstabilized austenite as cooling proceeds. The same conclusions have been reached for nickel steels containing 1% of carbon, and for eutectoid plain carbon steels.[2]

DISCUSSION

Progress of Martensitic Transformation

The progress of martensitic transformation in the carburized Krupp steel at different carbon levels is shown in Fig. 8. All the curves approach the abscissa asymptotically as the temperature approaches absolute zero. There were indications that the curves deviated from linearity near M_s, a phenomenon often observed in commercial steels. Ko and Morgan,[2] finding no such deviation in the progress curves for a laboratory melt of Fe–C–Ni alloys of high homogeneity, suggest that this deviation from linear relationship near M_s is caused by the heterogeneity of the commercial steels. The approximate M_s temperatures indicated in Fig. 8 should not be compared with published results of M_s in Krupp steels of lower carbon content, owing to the uncertain effect of the carbon gradient. There is an indication, however, that the rate of lowering of M_s with increasing carbon content is greater in the Krupp steel than in plain carbon steels.

Isothermal Stabilization

The present investigations show that isothermal stabilization can take place in Krupp steel at room temperature, at least above 0·9% of carbon, and the effect of stabilization when the specimens were held for 22 hr. at room temperature can be removed by further quenching to — 79° C.

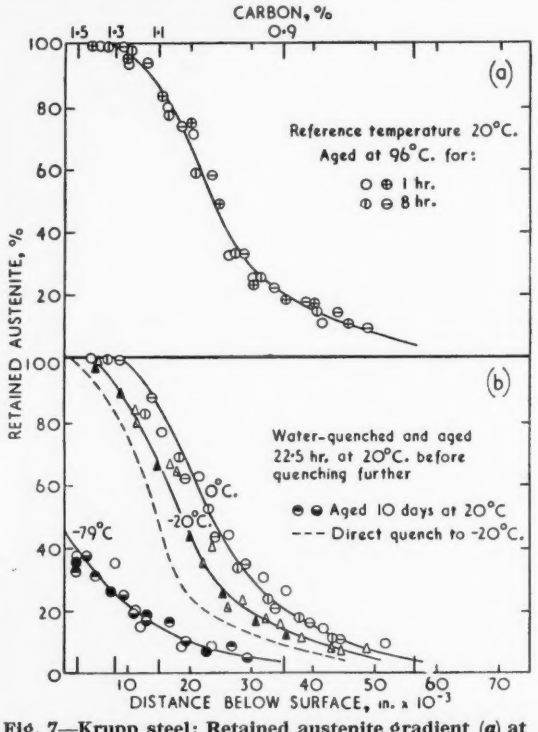


Fig. 7—Krupp steel: Retained austenite gradient (*a*) at 20° C., after ageing at 96° C., (*b*) after ageing at 20° C.

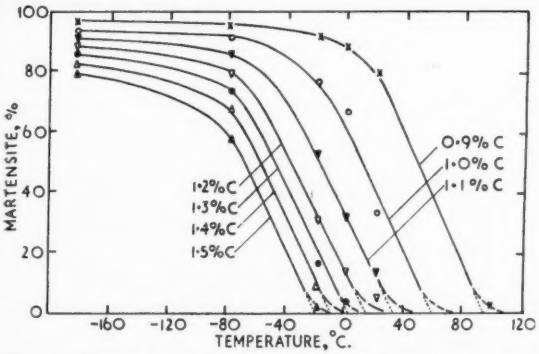


Fig. 8—Krupp steel: Martensite transformation curves

Stabilization in a Krupp steel has been previously observed[10] by means of X-ray methods. Patterns taken after quenching to room temperature and to — 79° C. indicated the presence of small quantities of austenite in a 0·89%-C Krupp steel austenitized at 800° C. Measurements of lattice parameter showed that the austenite contained only 0·66% of carbon in solution, the remainder being in the form of carbides. Quenching to room temperature and holding for several hours before cooling to — 79° C. yielded diffraction patterns with relatively strong austenite lines. Judging from the intensity of these lines, it was concluded that very little of the austenite retained at room temperature transformed to martensite on subsequent cooling, after the specimens had been at room temperature for several hours. This indicates that the ease with which the effect of stabilization can be removed by further quenching depends on the degree of prior transformation.

McReynolds[18] studied the effect of cooling rates in 0·4%-carbon Krupp steels, varying the rate of cooling from 1° to 100° C./sec. above M_s (260° C.) and from 2° to 14° C./sec. between M_s and 120° C., which is the point of 90% transformation. No difference in M_s or in the temperature of a given transformation was observed within the experimental scatter (about 6–8° C. in M_s and up to 20° C. for the temperature of 75% transformation). This could be due to two reasons: (i) The degree of stabilization in a 0·4%-carbon Krupp steel is small compared with the experimental scatter; and (ii) the stabilization is fast at high temperatures, owing to the presence of chromium, and the specimens cooled at the maximum rate used represented already fully stabilized specimens. The curve (*loc. cit.*,[18] Fig. 8) obtained when the cooling of the specimen was interrupted at 230° C. and the same specimen was reheated to and cooled from 360° C., shows that the transformation did not resume at 230° C. but at about 6° C. lower, a sign of some stabilization. Indeed, Sadovsky and Chuparkova's results[19] for Krupp steels with 0·3–0·4% of carbon in the temperature range where isothermal decomposition was not involved (below about 200° C.) indicate that stabilization due to isothermal holding had occurred, and the degree of stabilization increased with increasing holding temperature and time (*loc. cit.*,[19] Figs. 5 and 10). They also found (*loc. cit.*,[19] Fig. 6) that, after holding for 30 min. at various temperatures, more austenite was retained on air-cooling than on water-quenching to room temperature, provided that the holding temperature was above 250° C.* This is consistent with Ko and Morgan's finding[2] that there is a temperature S_0 above which no stabilization can take place (S_0 lies between 375° and 400° C. in a 1·1% carbon, 5% nickel steel), but stabilization will set in rapidly just below this temperature, giving rise to different austenite contents after cooling to room temperature at different rates.

Acknowledgments

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* The chemical composition of the austenite may be affected by the intermediate transformations, the incubation period of which should be about 1 min. at 350° C. (*see* "Atlas of Isothermal Transformation Diagrams," United States Steel Companies). But the austenite, after a given time of holding at a certain temperature, should be the same, and it is valid to compare the effect of cooling rate after holding for a fixed time at the same temperature.

The Drawing of Steel Wire at Elevated and Sub-Normal Temperatures

By

F. C. Thompson, D.Met., M.Sc., F.I.M.,

J. B. Carroll, M.Sc.,

and E. Bevitt, M.Sc.

SYNOPSIS

Before the effect of hot drawing on the properties of steel wire can be thoroughly investigated, a lubricant is required capable of withstanding the very severe conditions encountered. The best lubricant examined—a dispersion of semi-colloidal graphite in white spirit—behaved excellently up to 625° C. With an improved heating technique, higher temperatures could almost certainly be attained. The importance of a lime coat was again evidenced.

A low-speed drawing apparatus and the means of measuring the die load are described. The factors which influence the power requirements are discussed and a working hypothesis explains the changes in drawing load with temperature.

Tensile tests carried out on the hot-drawn wires during ageing up to ten months gave results which are not without promise. Mild-steel wire drawn at 625° C. (the die temperature was probably 675° C.) was still springy. Recrystallization was, therefore, far from complete.

The effect of low drawing temperatures (−40° C.) on the die load has been measured for a range of lubricants, of which the best of the wire-drawing soaps were the most efficient.

No substantial improvement in the tensile properties is to be expected from lowering the drawing temperature, but this conclusion is not final. There is no reason to doubt that cold-drawing could be carried out without difficulty down to −70° C.

The important effect of heating in the die due to friction and deformation has been considered.

To summarize, wire has been drawn satisfactorily in the temperature range from −40° to 625° C., and there is little doubt that this range could be extended in both directions. 717

PART I—HOT-DRAWING OF MILD-STEEL WIRE

WIRE-DRAWING above room temperature is not a new process; tungsten, molybdenum, and, more recently, high-speed steels have been drawn industrially at elevated temperatures. The possible advantages of hot drawing include: (1) Superior mechanical properties; (2) variations—or the elimination if the temperature is sufficiently high—of the ageing characteristics; (3) less power consumption; and (4) spontaneous recrystallization on emerging from the die, the material thus being soft and requiring no annealing.

Lubrication was the essential problem; given adequate lubrication, the actual drawing presented little or no difficulty. Most of the work has been carried out at quite low drawing speeds on a 'live' machine, and at still lower speeds on a dead-loaded machine. The latter tests are extremely severe so far as the lubricant is concerned, and it is probable that the behaviour of several of the lubricants would be improved at higher speeds.

Some of the earliest work on the drawing of steel wire above room temperatures was that of Pomp and Knackstedt,[1] who, in 1928, drew patented steel wire 5 mm. in dia. at temperatures up to 300° C. Francis[2] drew mild steel with a variety of lubricants up to 150° C., and in all cases found a significant fall in the drawing load. Kenneford and Thompson[3] showed that, with soap as lubricant, the drawing load fell smoothly to a temperature of 175° C., when the decomposition of the lubricant caused the load to rise steeply and drawing became impossible.

Apparatus

Of the three types of drawbench used, the first, a dead-load machine, and the third, used for drawing at a speed of 46 ft./min., have been described elsewhere.[4] The new apparatus, on which most of the work was carried out, is shown diagrammatically in Fig. 1.

The block was driven by a ¼-h.p., A.C. motor (*A*), the reduction being through worm and chain and sprocket gears (*B–D*) to give a constant drawing speed of 3·4 ft./min. The wire to be drawn was coiled on the swift (*F*), from which it passed through the small-bore copper tube (*G*), along the axis of the furnace (*H*). On leaving the tube (*G*) the wire made contact with the thermocouple hot-junction, and then was drawn through the die (*I*). A drilled cylindrical block (*J*) supported the die inside the furnace by virtue of the drawing force, and also separated the

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Dr. Thompson is Professor of Metallurgy and Mr. Carroll and Mr. Bevitt were formerly in the Department of Metallurgy at the University of Manchester.

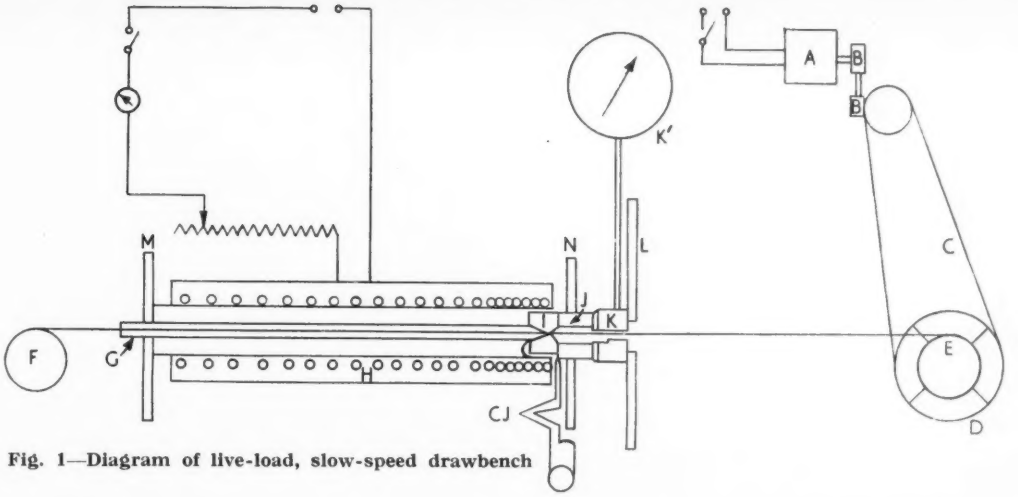


Fig. 1—Diagram of live-load, slow-speed drawbench

hot die from the statimeter unit (*K*) which measured this force. The unit was clamped against the rigid die plate (*L*) and the wire was drawn on the rotating block (*E*). Two asbestos sheets (*M*, *N*) sealed the furnace as far as possible and sheet *N* safeguarded the statimeter unit from overheating. The load was measured directly on the disc of the statimeter (*K'*).

The advantages of this machine, as compared with the dead-load bench, are:

(1) Tests could be carried out much more quickly
(2) Holding the wire in the furnace before drawing on the dead-load machine had a very bad effect on the lubricant. In the live-load machine the wire was continuously moving through the furnace and the period of baking was greatly diminished
(3) On the dead-load bench the static resistance which had to be overcome before drawing commenced was often considerably greater than the dynamic load, when measurements at constant drawing speed were difficult to obtain.

The heating equipment of the 'high-speed' machine is shown in Fig. 2. A specially designed swift was enclosed in a well-lagged, cylindrical, gas-heated pan furnace, and to maintain, as far as possible, a neutral atmosphere, a pan of charcoal was placed on the bottom. From the swift the wire passed direct to the die, which was itself heated to the required temperature in an electric furnace. Lubrication was carried out on the cold wire, the lubricant being baked on the wire during heating. In an alternative method the lubricated wire passed through a curtain of flame some two feet long, obtained by the combustion of specially prepared gas–air mixtures; the lubricant was thus subjected to the high temperature for a very much shorter time before drawing.

The temperature measurement of wire drawn at a fairly high speed presents some difficulty. The most successful method tried consisted in brazing the thermocouple wires to a piece of copper strip which rested on the wire immediately before it entered the die (Fig. 3). The pipeclay insulators on the couple had sufficient weight to hold this saddle in contact with the moving wire, and although the method is not entirely satisfactory, it is probably reliable to $\pm$ 10° C. when checked against lubricants of known flash points.

The material used in the live-load tests was bright-annealed mild-steel wire with an original diameter of 0·0475 in. After pointing, it was degreased by being rubbed with a piece of cotton wool soaked in benzene and an even coat of lubricant was similarly applied. The wire tested on the dead-load and the 'high-speed' benches was first drawn down to the sizes shown in Table I (about 0·068 in.), annealed, limed, pickled, and then baked at 200° C. for 1 hr.

Tungsten carbide dies were used throughout. They were almost new, *i.e.*, run-in, and in excellent condition. They had a slight radial taper, the effective semi-angle of the die being 5°, with a slight, possibly unintentional, parallel extension:

Results

The main results are summarized in Table I, of which the following notes are some amplification:

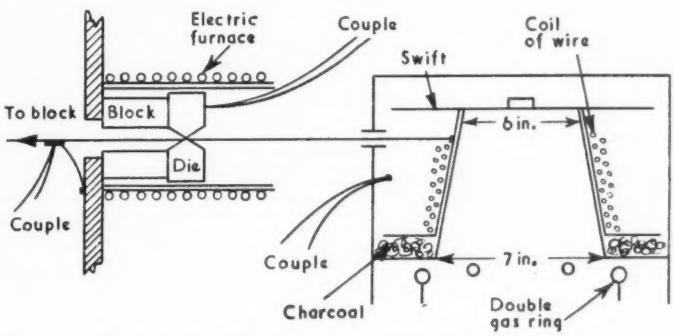


Fig. 2—Heating arrangement for 'high-speed' machine

Table I—SUMMARY OF RESULTS

Drawing speeds: Live load, 3·4 ft./min.; dead load, 2 in./min.; high speed, 46 ft./min.

Lubricant	Testing Machine*	Red. in Area, %	Orig. Dia., in.	Drawing Load at 15° C., lb.	Min. Drawing Load, lb.	Temp. of Min. Drawing Load, °C.	Temp. at start of Marked Rise of Drawing Load, °C.	Temp. at which Drawing Becomes Jerky, °C.	Drawing Load at 200° C., lb.	Max. Temp. of Test, °C.	Drawing Load at Max., Temp., lb.	Remarks	See Fig.
Lead, solder, copper	L	10	0·0475	Unsatisfactory									...
Aluminium stearate (i)	D	19	0·071	119	117	52	...	...	...	100	118	Single lime coat	4
(ii)	D			80	61	150	150	200	80	210	80	Multiple lime coat	4
Silicones													
Grease *DC4*	D	11·6	0·0675	72	...	...	...	<200	70	200	70		...
,, *DC44*	D	11·6	0·0675	85	...	...	...	,,	95	200	95		...
Fluid *DC710*	D	11·6	0·0675	96	...	...	...	,,	107	200	107		...
Grease *DC44*	L	10	0·0475	33	30	130–240	240	320	45	360	63	All unsuitable, but much better on live-load machine than on dead-load machine	...
,, *DC41*	L	,,	0·0475	40	40	15–130	270	...	30	440	75		...
Fluid *DC710*	L	,,	0·0475	42	42	15	15	15	51	320	75		5
,, *DC710G*	L	,,	0·0475	39	35	230–350	350	15	37	460	69		5
Hydrocarbons													
Oil *RD4*	D	11·6	0·0675	76	...	...	...	<200	77	200	77	Unsuitable	...
Oil *E2028*	D	,,	0·0675	75	...	...	...	200	88	200	88	,,	...
Grease *FK14*	D	,,	0·0675	76	...	...	...	200	90	200	90	,,	...
Grease *FS16*	D	,,	0·0675	53	...	...	...	200	Will not draw at 100	200	100	,,	...
Hypoid 90	D	,,	,,	Unsatisfactory									
Hypoid additive	D	,,	,,										
Red X	D	,,	,,										
Petromer Pale A	L	10	0·0475	30	26	170	170	15	34	490	60	Unsuitable	6*a*
EBS92	L	10	,,	30	30	15–100	100	440	33	575	62	Good performance	...
Tetra cresyl silicate	L	10	,,	35	35	15–50	300	15	44	430	55–75	Unsuitable	...
Phosphatized coatings	D	11·6	0·0675	Unsatisfactory									
Oildag and graphite in other hydrocarbons	D	,,	,,	Unsatisfactory									
Graphites in water													
Aquadag	L	10	0·0475	25	20	75–125	360	485	22	570	78	Good	6*b*
Prodag *B*	L	10	,,	20	20	15	450	>560	23	625	50	Very good	6*c*
Prodag *C*	L	10	,,	22	20	30–125	,,	500	,,	600	56	Nearly as good as *B*	...
Product 660 *A*	L	,,	,,	17	17	15		Not jerky	23	550	75	Very good performance	...
Product 660 *B*	L	,,	,,	17	17	15		,, ,,	20	575	75		6*d*
Graphite in volatile media													
Benzene-dag	D	12·7	0·068	84	53	250	250	400	52	400	?	Irregular	9
	H	20	0·0635	74	42	160	160	Not jerky	52	400	70	Good	9
	L	10	0·0475	28	19	90–175	175	205	24	380	55	Good	6*e*
Colloidal graphite in white spirit	L	,,	,,	21	19	300	300	575 Still smooth at	23	625	54	Very good	6*f*
Semi-colloidal graphite in white spirit	L	,,	,,	18	18	15–100	400	600	21	600	48	Best lubricant used	6*g*
Colloidal graphite in alcohol	L	,,	,,	29	23	250	450	400	24	625	63		...
Semi-colloidal talc	L	,,	,,	24	24	15	15	15	35	330	65	Bad	...
Colloidal mica	L	,,	,,	26	26	15–140	140	15	40	240	64	Bad	...

* L = live load, D = dead load, H = high speed

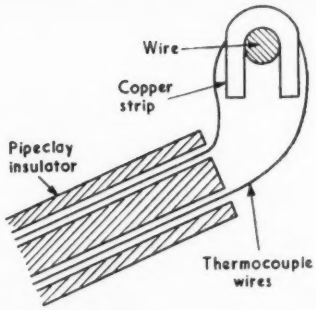


Fig. 3—Thermocouple for measuring temperature of wire

Lead—Although successful as a cold-drawing lubricant for certain high-alloy steels, lead was quite unsuitable for high-temperature work. The difficulty of wetting the wire may in part have contributed to this, but neither a zinc chloride flux nor 'benzenedag' gave any marked improvement. The lead–tin eutectic was no more satisfactory.

Copper—At room temperature a chemically deposited copper coat, if the wire is drawn while the deposit is still wet, is, of course, very satisfactory. When the deposit dried, however, it tended to peel off and above 150° C. oxidized and scored the die. Copper deposited electrolytically on a graphite undercoat showed some promise, and further investigation may be justified.

Aluminium and Calcium Stearates and mixtures of the two with a single lime coat gave irregular drawing and a high die load (Fig. 4), but a wire limed and dried four successive times* showed a marked improvement (Fig. 4). Since these tests were carried out only on the dead-load machine it is unjustifiable to reject this material without further examination.

Silicones—Grease *DC*4, a smooth, colourless jelly, was tested on the dead-load drawbench only. At 200° C. it appeared to decompose, leaving a hard, crusty mass on the wire, and drawing became impossible. Grease *DC*44, a silicone grease thickened with a metallic soap, was useless on the dead-load machine at 200° C. On the live-load machine drawing was not seriously uneven until about 320° C. At 360° C. the drawing load was twice that at room temperature, and drawing was very jerky. Grease *DC*41, similar to *DC*44, but thickened with very finely divided carbon black, was more satisfactory.

The two fluid products, *DC*710 and *DC*710*G*, differ only in that the latter contains approximately 5% of colloidal graphite. On the dead-load machine *DC*710 was most unsatisfactory; on the live-load apparatus drawing was impossible above the flash point (320° C.). A marked improvement resulted from the addition of graphite (Fig. 5). *DC*710*G* was the best of the silicone products tested.

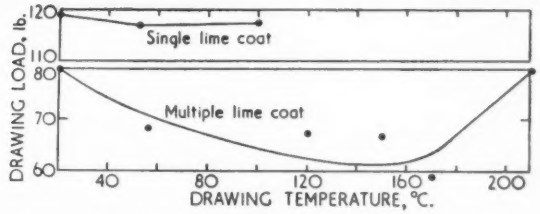


Fig. 4—Drawing-load/temperature curve obtained on dead-load bench

Hydrocarbons—*E*/2028 was a heavy oil, which ran quite freely; *RD*4, a very thick, black oil with the consistency of treacle; and *FK*14 and *FS*16 were black- and putty-coloured greases. In each case, due to the decomposition of the oil, a coked mass was left on the wire at 200° C., a high drawing load was required, and the drawing was unsatisfactory. Grease *FS*16, however, was the best room-temperature lubricant examined and is comparable with the best soap, 3535, used by Francis.[2] It appears to consist of a mixture of saponifiable and hydrocarbon oils, with about 25% of colloidal inorganic matter.

Three high-temperature, high-pressure motor oils were examined, but were unsuitable at both room and elevated temperatures.

Lubricant *EBS*92, used in *A*30 oil showed little decomposition at 220° C., and from this temperature the drawing load increased gently to the end of the test. Drawing was uneven at 440° C., but continued up to 575° C. (Fig. 6*a*). This material is without doubt the best of all the oil-base lubricants examined.

Phosphated Coatings—Three of these were Bonderized and one was Parkerized. Only very short samples were available and it was impossible to carry out comprehensive tests. No lubricant was applied to the wire, and such coats may have greater possibility as carriers of other lubricants. From the results it may be inferred that the thinner the Bonderized coating, the better, but it seems that these coatings by themselves are useless for high-temperature drawing.

Graphite Dispersions—The first group included graphitized wax, colloidal graphite in lanolin, etc. All

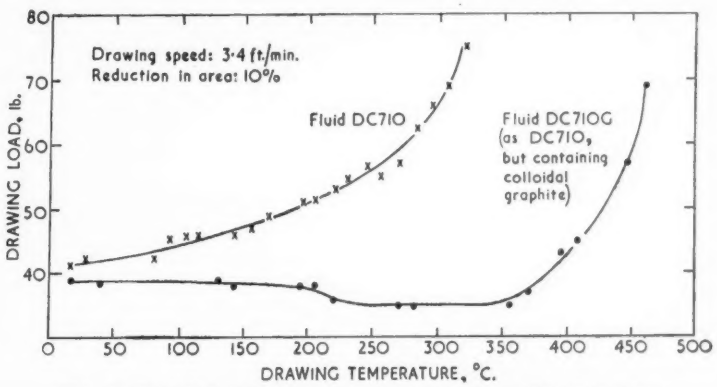
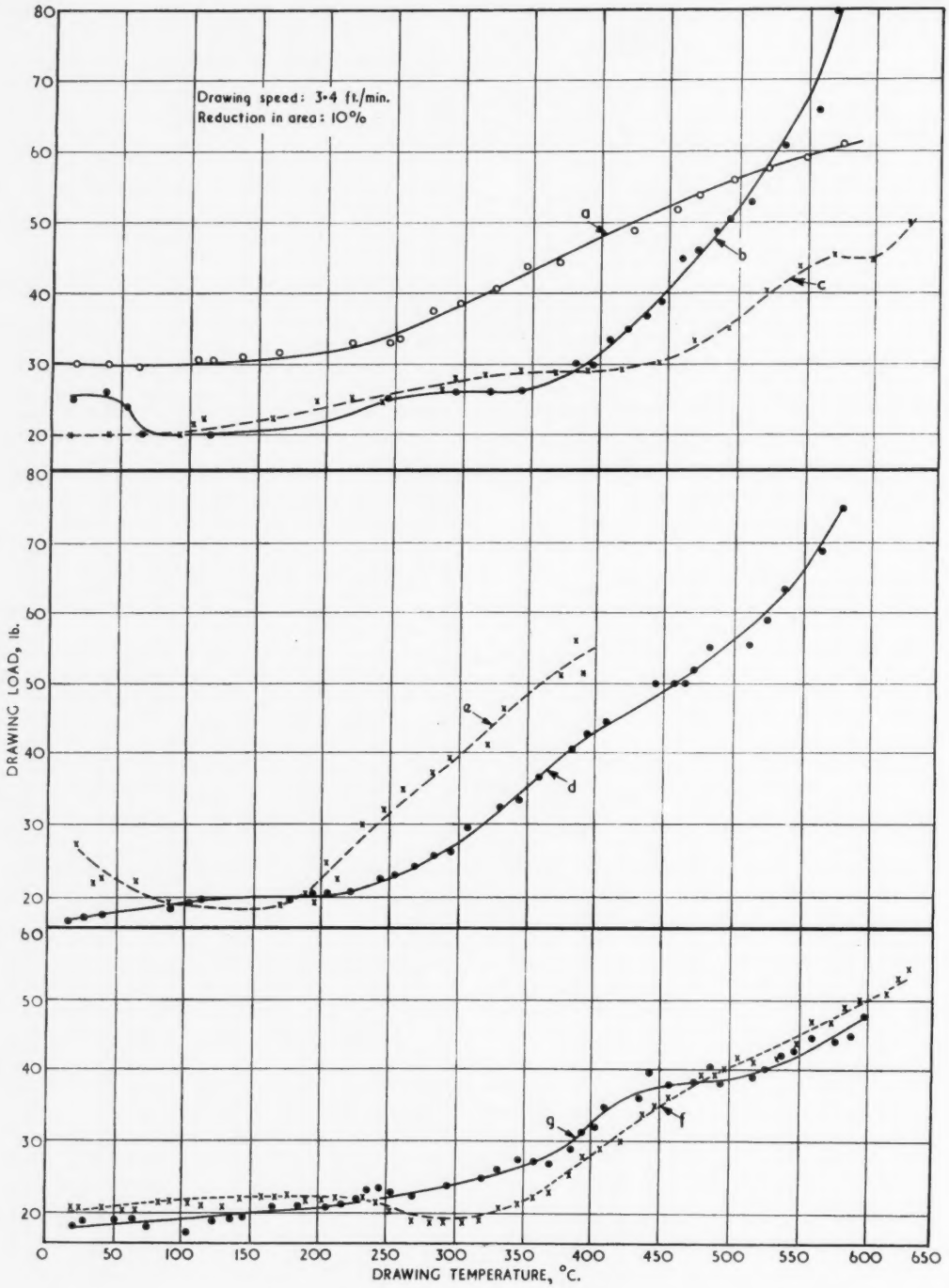


Fig. 5—Drawing-load/temperature curves for mild-steel wire lubricated with silicone fluids

* This procedure was suggested by Mr. J. H. G. Willan.



Lubricants

(*a*) 10% *EBS*92 in transformer oil *A*30
(*b*) Aquadag (colloidal graphite in water) diluted with 2 parts of water + wetting agent
(*c*) Prodag (semi-colloidal graphite in water), grade *B*, diluted with 1 part of water + wetting agent
(*d*) Product 660*B* (semi-colloidal graphite in water) + wetting agent
(*e*) Colloidal graphite in benzene
(*f*) Colloidal graphite in white spirit
(*g*) Semi-colloidal graphite in white spirit

Fig. 6—Drawing-load/temperature curves for mild-steel wire with various lubricants

were valueless for high-temperature drawing, since the oil or wax base charred, leaving, even at 200° C., a hard, undrawable deposit on the wire and in the die mouth.

With Aquadag it was difficult to get the lubricant to wet the wire, and there was a tendency to corrosion. The former trouble was overcome by a wetting agent, but this seemed to increase the corrosive behaviour.

Drawing at a reduction in area of 10% was smooth up to 485° C., the surface of the wire being completely covered with a graphite coat, though the drawing load rose sharply at about 360° C. (Fig. 6*b*).

Other products in this class were much more satisfactory. A semi-colloidal dispersion of graphite in water has been used industrially for drawing high-speed steel. Diluted with one part of water and with 2% by volume of the wetting agent, grade *B* was slightly better (Fig. 6*c*). With both materials the wire had a ' graphoid ' surface. With grade *C*, drawing was jerky at about 500° C., and at 560° C. distinct necking occurred. With grade *B*, drawing was still smooth at the higher temperature.

Products 660*A* and 660*B* contained as little extraneous matter, such as stabilizers, etc., as possible. The graphite particles in both are of a ' semi-colloidal ' nature, those in 660*B* being larger than in 660*A*. The curve for 660*B*, which was slightly the better of the two, is shown in Fig. 6*d*.

The most interesting of all the graphite dispersions tested were the four in volatile media: colloidal graphite in benzene, white spirit and alcohol, and a semi-colloidal preparation in white spirit. Until a late stage in the progress of this research the colloidal graphite in benzene (Fig. 6*e*) had been the most satisfactory hot-drawing lubricant. A smooth continuous coat of graphite was obtained and drawing occurred smoothly and with relatively low loads up to about 400° C. A disadvantage of this material is that the dispersion seems to contain a small amount of oily matter, possibly as a stabilizer. On heating, this matter charred, although not sufficiently to interfere seriously with drawing. However, the graphite coat produced continued to lift on heating, leaving the wire locally bare or only loosely covered. This may be due to gases given off from the small amount of hot oil bursting through the graphite shell.

The suspension containing 10% of colloidal graphite in white spirit, again with a little oily matter, coated the wire extremely well. This lubricant is much superior to the dispersion in benzene. Drawing was smooth up to 575° C. with a more or less minimum drawing load up to 350° C., and although above 575° C. drawing was slightly uneven this lubricant was satisfactory up to 625° C. (Fig. 6*f*).

The semi-colloidal graphite dispersion in white spirit, product 669, contains very little oily matter. Drawing was still smooth at 600° C. and showed no indication of deterioration, the load increasing steadily. This was the best material examined (Fig. 6*g*).

Dispersions of talc and of mica were both unsatisfactory.

Summing up the results, the only lubricants to which special attention need be drawn are the hydrocarbon-based material *EBS*92 in transformer oil *A*30; and the graphite suspensions in white spirit, which were quite outstanding, particularly the semi-colloidal graphite. The size of the graphite particles is very significant—a fact which is further demonstrated by the difference in the behaviour of the semi-colloidal dispersions of graphite in water.

The major portion of the work has been done deliberately at low drawing speeds, since a lubricant that will stand up to these conditions may be expected to behave better at higher speeds. Any lubricant, therefore, which has shown promise in these low-speed tests may be worthy of more extended trial under industrial conditions.

Discussion of Results

Two types of lubricant are dealt with: (1) those susceptible to heat and (2) those which are allegedly inert. The former will, at some critical temperature, begin to decompose or volatilize, when the drawing load would be expected to increase. If the lubricant consists of a number of constituents, each with its own temperature of decomposition or volatilization, the increase in load should take place in a series of steps. However, the removal of a certain constituent might have a beneficial effect on lubrication, if, for instance, the constituent removed were a bad lubricant in itself. The load might then temporarily decrease.

Although the ignition temperature of graphite is given by Stuart[5] as 650–700° C., it absorbs gases, the influence of which on the lubrication properties may be significant. Further, the ' graphoid ' coat, which results from the graphite being drawn through the die, greatly improves the lubricating properties. This coat in some cases is only formed somewhat above room temperature. For example, wire drawn at room temperature using colloidal graphite in alcohol, was bright and showed no sign of graphite. At 92° C. it began to come through on the wire, the drawing load being 30 lb.; as the temperature rose, more of the surface became affected, and it was totally covered at 220° C., when the load had fallen to 23 lb., almost 25%.

Several of the load–temperature curves show an initial drop in the drawing load as the temperature rises, a minimum, a maximum, a second minimum, and then a final rise. The operative factors appear to be a change first in the frictional effect, secondly in the hardness of the wire, and thirdly ageing,[6] either during the preliminary heating or in the die itself.

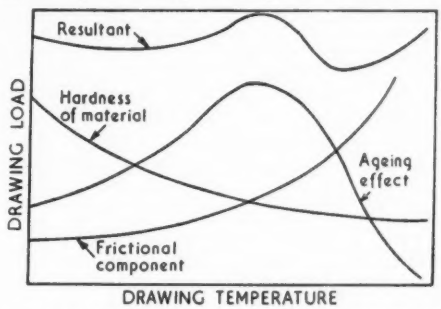
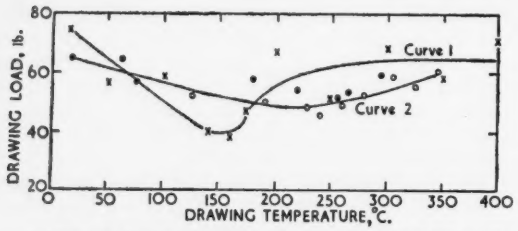


Fig. 7—Probable variation with temperature of the factors affecting the drawing load



× Curve 1: Annealed mild-steel wire; drawn 0·0635–0·058 in. dia.; reduction in area 18%; drawing speed 46 ft./min.

●○ Curve 2: 70/30 brass; two sets of results treated as one; drawn 0·064–0·057 in. dia.; reduction in area 20%; drawing speed 46 ft./min.

Fig. 8—Comparison of the drawing-load/temperature characteristics of mild steel and 70/30 brass, lubricated with colloidal graphite in benzene

Figure 7 shows qualitatively the probable variation with temperature of each of these factors; the curve for the net effect of these variations was very similar to that actually obtained.

In the absence of ageing, the curve to be expected consists of a smooth fall to a minimum, followed by a subsequent rise. Curve 2 of Fig. 8, for an α-brass, in which ageing is essentially non-existent, is exactly of this kind. Curve 1 shows the ageing effect.

Superposed on this general curve will be minor fluctuations, due to the evaporation or decomposition of individual constituents of the lubricant. Further, the 'low-temperature' abnormalities in steel, which influence the mechanical properties,[7] may also be playing a part, whilst in graphite lubricants, the adsorption of graphite to the surface, giving the 'graphoid' surface structure, will also be operative.

Several lubricants were tested at temperatures well above their flash points. Apart from the fire risk, drawing is frequently difficult or impossible above this temperature. Grease *DC*41, with a flash point of 270° C., gave a sharp increase of the drawing load at this temperature, and drawing was very jerky or impossible. Thus, it is not surprising that the actual curves are complicated.

The real drawing temperature of these wires is higher than that measured, by an amount dependent on the heat given out by the deformation and that generated by the friction, and it is desirable to obtain an estimate of the total effect. The practical difficulties of measuring the die–wire interface temperature and the wire temperature at exit have not, however, yet been fully overcome, and these temperatures are therefore given with reserve. In a theoretical treatment of the subject, Siebel and Kobitzsch[8] have derived expressions for the temperature rise and distribution obtaining in wire during drawing. On the basis of their results, and assuming that the other values remain essentially the same, the temperature rise due to friction in the present tests at 3·4 ft./min. for the best lubricants is a few degrees only and, compared with other experimental errors, can be neglected.

Again making the same assumptions, the 10% reduction in area used in many of the tests will cause a temperature rise due to deformation of, at most, 13–14° C. The total error of about 15° C., which must be added to the temperatures given for an approximation of the real temperatures of drawing, is less than expected. However, the temperature rise due to friction at the surface, which depends on the coefficient of friction, may be expected to increase when the lubricant deteriorates, so that at high temperatures there is a cumulative effect on the true surface temperature.

Dead-Loading versus Live-Loading; Effect of Speed of Drawing—In many instances a lubricant which behaved badly when drawn at the very low speed on the dead-loading machine was appreciably better on the live-load apparatus. The best illustration of this is given by the results for benzene-dag on the slow-speed dead-load machine and on two live machines at speeds of 3·4 and 46 ft./min. (Fig. 9), the reduction in area being 20% at 46 ft./min. and 10% at 3·4 ft./min. Broadly speaking, and taking into account the difference in reduction, the two live-load curves are comparable. The drawing load at the higher speed is roughly double that at the lower, as would be expected. This justifies the lower speed used in the major portion of this work, at least so far as the behaviour of the lubricant is concerned. Two points, however, need stressing: with the dead-load machine, the wire and the lubricant were exposed to baking for a much longer period and part of the bad result obtained may be due to a deterioration of the lubricating coat before drawing really commenced. This deterioration does not seem to have been due to oxidation—a nitrogen atmosphere gave little improvement—as much as to decomposition or flaking-off of the lubricant. Secondly, these curves emphasize the fact that tests on the dead-load machine are extremely severe.

Mechanical Properties of Hot-Drawn Mild-Steel Wire

Some mechanical tests were carried out on the wire both immediately after drawing and after ageing at room temperature for periods up to ten months.

The material tested was drawn at 46 ft./min., using colloidal graphite in benzene. The wire was reduced by 16·4% from an original diameter of 0·0635 in.

The tests were carried out on a Hounsfield tensometer. The results are collected in Table II, each being the mean of at least two tests on samples taken

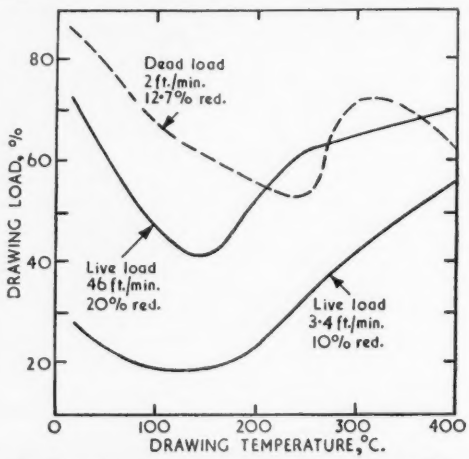


Fig. 9—Drawing-load/temperature curve for mild steel lubricated with benzene-dag

from opposite ends of the length drawn. The rate of straining was maintained as constant as possible. The maximum in the tensile strength around 120° C. is almost certainly associated with some strain-ageing effect. The secondary increase in strength above 250° C. may be even more important. The maximum in the elongation, around 150° C., is still equally marked after the longest periods of ageing.

It would be premature to attempt to discuss these results, but the values obtained after ageing for 10 months, especially for wire drawn at the higher temperatures, should be approaching stability. As regards the tensile strength, the wire drawn at the lower temperature tends to harden on ageing, that at the higher to soften.

Wires drawn at temperatures up to 625° C., *i.e.*, about 100° C. above that normally taken as the recrystallization temperature of cold-worked ferrite, were still distinctly springy. It is clear, therefore, that a still higher drawing temperature would be required for complete softening.

PART II—DRAWING AT SUB-NORMAL TEMPERATURES

Wire-drawing at sub-normal temperatures has two possibilities: (1) Retardation of ageing effects, (2) superior properties.

So far as the authors are aware, no systematic work on low-temperature drawing has been published, but in the *Scientific American* (Sept., 1946) it is stated that " some metals may be machined, upset, or otherwise fabricated much better at low temperatures." Much work has, of course, been done on the mechanical properties of steel and other materials at temperatures below normal, which has been admirably summarized.[10]

The present work was carried out in two parts: (1) Refrigerated wire was drawn through a die at atmospheric temperature; and (2) the die also was at the sub-normal temperature. The main feature was the technique of wire-drawing under these conditions, but tests were carried out on the wire produced and on its tendency to age. A wide range of lubricants has been examined, mainly in drawing mild steel, but also some medium and higher-carbon wires.

A live-load machine was used at a constant speed of 3·4 ft./min.

Experimental

The materials examined are detailed below:

Steel	C, %	Dia., in.	Condition
O	0·045	0·050	Annealed
E	0·086	0·0475	Annealed
T	0·035	0·0488	Annealed
L	0·70	0·0437	Air-patented and limed
B	0·70	0·038	Bright-drawn

Wires *O*, *T*, and *L* were slightly rusted, a fatal defect in investigations of this kind. They were therefore pickled, for 3–10 sec., in 1 in 60 nitric acid, followed by washing in hot water, after which the rust could be wiped off. Nitric acid was employed to eliminate any possibility of hydrogen embrittlement, and the wires so treated drew without difficulty.

A Prestcold cabinet-type refrigerator was used, the cold chamber being $21 \times 10\frac{1}{2} \times 16$ in. deep; the circulating medium was Freon 22. With the insulated, hinged lid in position the refrigerator was capable of reaching a minimum temperature of — 72° C. with a maximum variation of less than 2° C. In the earlier experiments the wire was placed in the cold chamber on a wooden swift, which rotated about a horizontal axis, and was thence conducted through a short insulated conduit to the die.

Table II

MECHANICAL PROPERTIES OF HOT-DRAWN MILD-STEEL WIRE

Drawing Temp., °C.	As Drawn	Aged 1 month	Aged 2 months	Aged 3 months	Aged 4 months	Aged 5 months	Aged 7 months	Aged 9 months	Aged 10 months
				Maximum Stress (tons/sq. in.)					
16	28·2	32·05	31·45	31·43	31·3	31·5	31·8	31·5	31·34
50	28·75	30·45	34·0	31·24	30·9	30·9	30·50	30·06	30·21
100	32·09	31·9	31·6	31·6	31·87	32·15	32·0	31·92	32·0
140	32·24	32·13	31·06	31·3	31·50	31·8	31·63	31·24	31·4
160	29·73	31·75	30·85	31·3	31·40	31·25	30·98	31·5	30·5
175	30·8	32·0	31·4	31·6	30·98	31·53	31·3	31·3	31·28
200	28·89	30·95	29·88	29·35	30·2	29·65	29·43	29·3	28·5
250	29·91	30·04	30·64	31·3	30·95	30·1	30·0	30·1	30·2
300	32·78	35·65	39·4	37·5	35·4	35·1	34·5	33·9	33·75
350	34·85	35·6	33·3	33·3	33·3	33·27	33·1	33·17	33·23
400	38·28	36·3	35·4	35·3	35·03	35·98	34·98	34·96	34·97
				Elongation on 2 in. (%)					
16	2·5	5·0	7·25	7·5	7·0	6·25	5·5	3·1	3·1
50	4·25	4·5	3·75	4·5	4·75	5·25	5·5	6·25	4·5
100	4·0	4·0	4·0	5·0	5·0	5·0	5·0	4·0	3·1
140	6·25	6·5	6·75	8·0	8·25	8·25	8·4	8·9	9·4
160	7·0	7·13	5·5	8·125	8·3	7·25	8·3	8·8	9·4
175	6·25	7·0	7·5	9·4	8·5	7·5	6·25	6·75	7·0
200	6·75	6·0	5·0	7·5	4·25	7·0	6·3	4·7	6·25
250	7·25	6·75	5·75	7·5	7·3	7·0	7·0	6·8	6·25
300	4·5	3·0	3·5	3·8	5·0	5·0	4·0	3·1	4·0
350	3·75	5·0	2·75	2·8	3·5	3·3	3·1	2·8	2·5
400	2·5	4·0	3·5	3·4	3·0	3·0	2·0	2·0	2·0

XUM

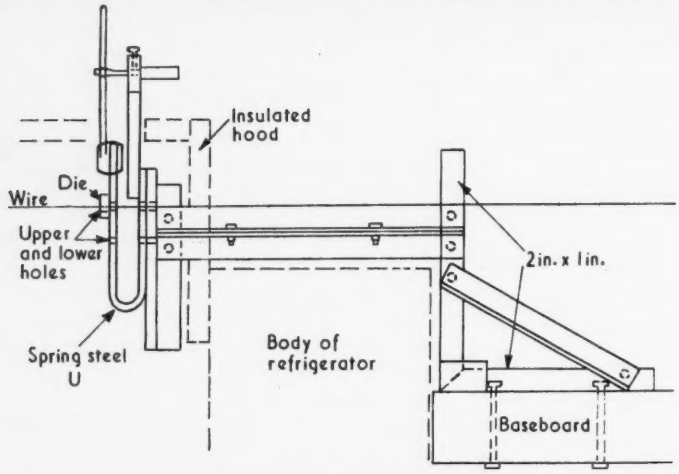


Fig. 10—Arrangement for low-temperature drawing tests with both wire and die at low temperature

For the tests in which the die also was at the low temperature the drawbench was extended into the cold chamber by superposing an insulated hood, into which it was accurately fitted (Fig. 10). The hood consisted of two thicknesses of asbestos sheet, the intervening space (about 1 in.) being filled with magnesian asbestos. As the cooling coil enclosed only the lower part of the chamber, to which the colder air gravitated, a considerable temperature gradient was set up when the hood was in position, to obviate which a circulation fan was introduced. Owing to the increased volume of the chamber and the consequently higher heat leakage, the lowest temperature attainable in the chamber during the later tests, *i.e.*, with the hood, was approximately — 40° C. Two closely contoured holes were cut into the side and the top of the hood, the former to allow the main members of the bench-head to pass through and the latter to allow the extended load-measuring device to protrude. It was important to ensure that mechani-

Table III

DRAWING TESTS ON MILD STEEL *O* REDUCED 39·16%

Lubricant	At R.T. (21° C.)			Die at R.T., Wire at — 70° C.		
	Drawing Load, lb.			Drawing Load, lb.		
	Max.	Min.	Aver.	Max.	Min.	Aver.
Germ R.O.D. wire-drawing paste	69·5	67·5	68	66	64	65
Hypoid 90	75	70	73	74	69·5	72
FK 14	79	76	77·5	...	...	...
FS 16	72	69	70·5	71	66	68·5
Oildag	73	69	71	70	68	69
Castor oil	71	69	70	69	64	66·5
Silicone fluid *DC710G*	79	76	77·5	74·5	71	73
Silicone grease *DC41*	79	76·5	78	71	69	70
Silicone grease *DC44*	76	74	75	74	71	72·5
Silicone fluid *DC710*	77	75	76	72	71	71·5
Dag in lanolin	69	66	68	66	63·5	64
Dag in diethylene glycol	74	71	73	70	66	68
Dag in castor oil	69	66	67	67	65	66
Brown soap 3535	65	62	63·5	73	70	71·5
Crossfield's brown wire-drawing soap	67	63·5	65	69	66	67·5
Hard sodium soap	64	61	62·5	71	64	67·5
Aquadag concentrated	71	66	68·5	73	66	69·5

cal contact did not occur between the hood and the drawbench to avoid the transmission of the vibrations of the latter to the measuring gauge.

The temperature of the chamber was measured by two copper–constantan thermocouples calibrated at the freezing points of water, mercury, and methyl iodide, one near the bottom of the chamber, the other in contact with the die casing.

The variations in the reading of the statimeter used in Part I to measure the drawing load and the need, therefore, for constant recalibration were a continual source of trouble. A much improved means of measuring the load was provided by the device employed by Baron,[9] which consists of a U spring which carries the die and through holes in which the wire passes to the block. The deflection of this spring measured by a dial gauge was calibrated by dead loading.

To eliminate the chatter which occurred when drawing the high-carbon steel wires and when using heavier reductions, extra rigidity was provided by an angle-iron strut placed between the bench-head and the top of the shaft carrying the block. Smooth drawing was then obtained even with considerably higher die loads.

Results

The first series of systematic tests was carried out on wire cooled to — 70° C., the die being at room temperature. Mild steel *O* was reduced 39·2% from an original diameter of 0·050 in. Table III gives results for a wide range of lubricants, together with the corresponding drawing loads for wire reduced to the same extent at room temperature. With the exception of *FK*14, with which the wire invariably broke a few inches from the die, drawing was consistently steadier at the reduced temperature, and no difficulty was experienced in drawing despite the severe reduction.

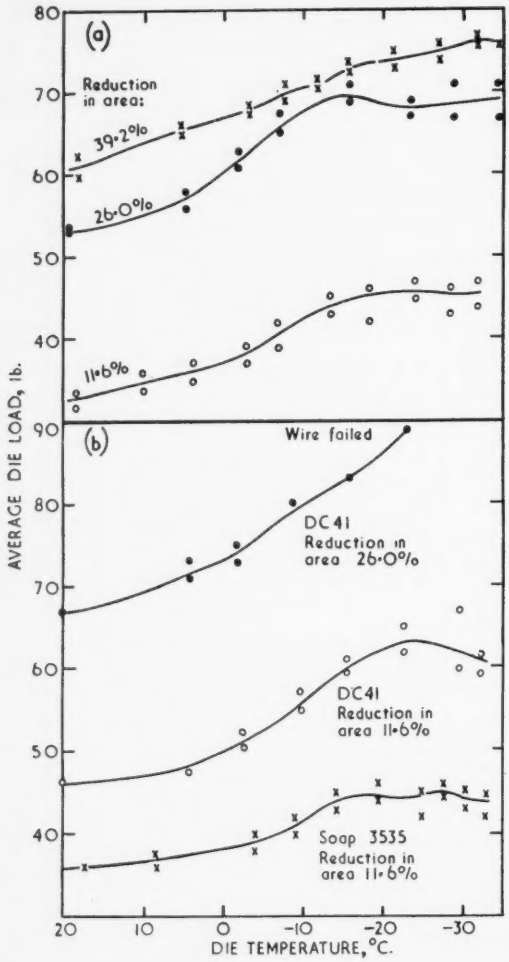
Although in the case of the soaps the drawing load was somewhat higher at the lower temperature, the general trend for the other lubricants, other than *FK*14 and the concentrated Aquadag, was slightly, but consistently, lower.

Table IV

DRAWING TESTS ON MILD STEEL *O*, ORIGINAL DIA. 0·05 IN.
Wire and Die at Same Temperatures

Lubricant	Reduction in Area: 11·6%						Reduction in Area: 26%						Remarks
	20° C.			— 35° C.			20° C.			— 35° C.			
	Average Load, lb.	Range, lb.	Remarks	Average Load, lb.	Range, lb.	Remarks	Average Load, lb.	Range, lb.	Remarks	Average Load, lb.	Range, lb.		
R.O.D.	36	36–40		46	44–48	Very steady	53	50–56	Quite steady	69	67–71		
Hypoid 90	44	42–49		56	55–59	Jerky	51	47–56		73	71–75		
FS16	33	31–34		49	46–52		49	47–50		62	59–65		
Castor oil	42·5	39–45		52	48–59	Unsteady	59	58–63		69	64–71		
Oildag	43	42–47		54	52–59		54	53–61		72	70–74		
Dag in diethylene glycol	39	36–40		45	38–52		59	56–63		83+	...		Wire failed
Silicone fluid 710G	48	46–52	Very unsteady	...	...	Pulled out	71	68–74	Quite erratic	75	68–80		" "
Silicone *DC*41	46	43–49		56	55–59		67	63–77	Unsteady	84+	...		" "
Silicone *DC*44	46	45–50		56	55–62		66	63–74	Unsteady	80	80–86		
Silicone fluid 710	45	44–49		55	54–57		68	67–71		78	74–82		Wire pulled out several times
Dag in lanolin	38	37–39	Very steady	56	?	Jerky, sucking 0·0006 in.	58	53–62		69	67–71		
Soap 3535	32	31–34	Very steady	46	44–50	Steady	51	50–52		61	59–64		
Dag in castor oil	43	42–46		57	52–64	Unsteady	59	58–67	Unsteady	76	74–78		
Crossfield's brown soap	34	33–35	Very steady	43	40–48		51	47–55		56	53–59		
Hard sodium soap	34	33–36		46	44–50		48	47–52		67	64–72		

XUM



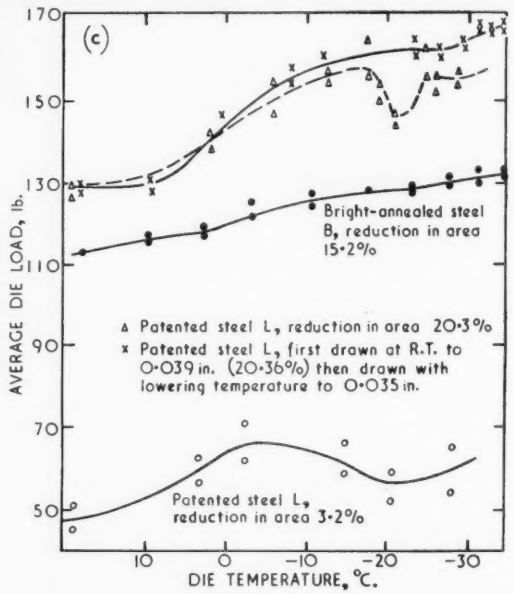

(c)
Bright-annealed steel B, reduction in area 15·2%
Patented steel L, reduction in area 20·3%
Patented steel L, first drawn at R.T. to 0·039 in. (20·36%) then drawn with lowering temperature to 0·035 in.
Patented steel L, reduction in area 3·2%
AVERAGE DIE LOAD, lb.
DIE TEMPERATURE, °C.

Fig. 11—Drawing-load/temperature curves for: (*a*) Steel *O* (0·045% C), using Germ R.O.D. wire-drawing paste; (*b*) steel *O* (0·045% C), using silicone *DC*41 and industrial soap 3535; and (*c*) high-carbon steels *L* and *B*, using Germ R.O.D.

The real temperature of drawing in these tests can be estimated only very roughly. In some cases, however, the frost on the wire melted just before it entered the die due to a feed-back of heat from the latter. It is probable, therefore, that for the less efficient lubricants the drawing temperature was slightly above 0° C., and for the better ones somewhat below 0° C. If this is so, the reduction of the drawing load is understandable, since there is good reason to believe that the tensile strength of ordinary mild steel is a minimum at about that temperature before rising again as the temperature falls further.

With both the die and the wire at the reduced temperature, reductions of 11·6 and 26% were used with 15 lubricants. A reduction of 39% was invariably unsuccessful at the low temperature, as was a 26% reduction with the poorest lubricants. The results are given in Table IV.

The outstanding result was the excellent behaviour of the Crossfield brown soap, particularly with the heavier reduction. Of the other lubricants Germ R.O.D. and Dag in diethylene glycol may be mentioned. In several instances, the drawing load fell slightly as the test proceeded, due presumably to heating of the die.

Discussion of Results

Only one lubricant, Dag in diethylene glycol, remained completely fluid at — 70° C. The physical state of the lubricant, *i.e.*, solid or fluid, at the low temperature does not, however, seem to be important, and under the high pressures at the die–wire interface its condition will most certainly be modified. The lubricant coat, however, must remain firmly adherent at the low temperature and neither crack nor flake off during uncoiling from the swift or upon entry into the die. Some empirical bend tests suggested that no difficulty would in general be encountered on this account.

Influence of Temperature on the Drawing Load—From Table III it will be seen that, with the die at room temperature, eight lubricants show a pronounced fall and three a definite rise in the drawing load at the low temperature. The grease-based lubricants all tend to give a lower drawing load at the lower temperature, the fall varying up to 10%. The three soaps, on the other hand, showed a rise in load of 4–12% as the temperature was lowered. Aquadag, which dried very shortly after application to the wire, leaving a thin, even film of graphite, was little affected. Considering the range of lubricants as a whole, the minimum load at room temperature (62·5 lb. with sodium soap), is only slightly lower than that for the low temperature (64 lb. with Dag in lanolin).

Lowering the temperature of the die and of the wire to — 35° C. (Table IV) decidedly increased the drawing load in each case. For the lower reduction of 11·6% the average drawing load increased by 15–45% for a 55° C. temperature fall. Of the five most efficient lubricants at normal temperatures four were among the five most efficient at — 35° C., this also being true for the higher reduction of 26%. At the low temperature, the wire would not withstand a reduction of 26% with several of the poorer lubricants, but no difficulty was experienced with the better ones. With a reduction of 39% the wire drawn at — 35° C. invariably failed, irrespective of the lubricant used.

The surface finish of the wires drawn at the low temperature with the more efficient lubricants was good, especially with the soaps, which gave a smooth, mat finish.

Figure 11 shows a rise in drawing load as the temperature of drawing is reduced. The rate of increase is slow at first, but increases over the range 0–25° C., depending upon the lubricant and the reduction increments. The most noticeable point in the curves for the lighter reductions is that, at about — 20° C., the drawing load ceases to rise, and in certain cases even falls. This phenomenon is absent in the curves for heavier reductions, *e.g.*, 39% with Germ R.O.D. and 26% with the poor lubricant silicone *DC*41.

For the high-carbon steels in the patented condition, the drawing load rises with falling temperature; but at two different reductions, one light and the other much heavier, steel *L* shows a fall in the drawing load at — 20° C., after which the curve again rises. Several independent draws confirmed this fall. Tests on steels *B* and *L* in the previously drawn condition show that, whatever the cause of the drop at — 20° C., it was removed once the steel had been worked, after which the drawing load increased steadily with falling temperature down to about — 40° C., the limit of the tests.

The effect of heating due to deformation and friction upon the properties of the wire is important. Adopting the formulae of Siebel and Kobitzsch,[8] the temperature increases due to deformation (t_i) and that resulting from friction (t_a) have been calculated for several of the low-temperature tests recorded. The values of the mean yield stress, allowing for the effect of temperature, and the factor m have been somewhat overestimated so that the results should be a maximum.

In the results of Table III, it is curious that, with the exception of the soaps, the drawing load falls as the temperature is reduced—probably to around, or just below, 0° C. This is still more surprising if the strength of the material is simultaneously rising. In contrast with these results, Table IV, where both die and wire were at — 35° C., shows in every case an increased drawing load.

It appears that, as the temperature of drawing falls from 20° to — 35° C., the load passes through a minimum at about 0° C., and then starts to rise again somewhat sharply. So far as the lubricant is concerned, it might be expected that its increased viscosity at the lower temperature would increase the viscous drag into the die, and the stability of the film formed would also be increased. From this point of view, then, the drawing load should fall with temperature. The explanation is therefore to be looked for in some change in the mechanical properties of the steel.

If the following values may be taken as approximately correct, the 'true' drawing temperature corresponding to the results contained in Fig. 11 may be calculated:

Steel	Reduction, %	t_i, ° C.	t_a, ° C.
O	11·6	10	Small
O	26·0	30	,,
O	39·2	62	,,
L	20·3	52	,,
B	15·2	35	,,

This has been done for the patented steel *L*, reduced 26% with Germ R.O.D. lubricant, using typical, average values, and is as follows:

Nominal Drawing Temp., ° C.	'True' Temp., ° C.	Drawing Load, lb.
20	72	128
2	54	140
— 5	47	149
—13	39	153
—22	30	143
—26	26	153
—38	14	183 (?)

There appears to be nothing incredible in these values, and the general shape of the curves of Fig. 11 may, therefore, be ascribed in the main to changes in the mechanical properties of the material, modified possibly by some change in the friction with lowered temperature.

The extent—and it is considerable—to which the lubricant affects the load will be appreciated from Figs. 12*a* and *b* for mild steel *O* with, in each case, a reduction of 11·6%. The general shape of each of the three curves for the soap 3535, silicone *DC*41, and Germ R.O.D. is, however, essentially the same. Figure 11*c* shows three curves for the same material and lubricant and differing only in the reductions. A truer picture of these results is given in Fig. 12, in which the corrections to the nominal drawing temperature given above have been applied. With the severest draft the 'true' temperature never falls below about 25° C. There is a general similarity in the shapes of these curves which supports the treatment adopted.

From these results it is apparent that, if drawing of the harder steels at commercial speeds and with high reductions is desired, a much more efficient type

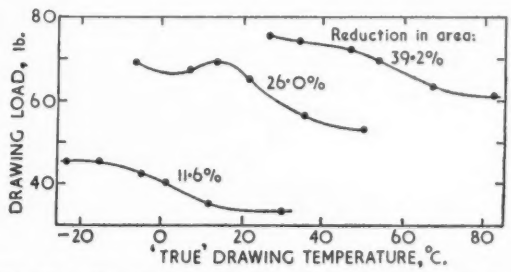


Fig. 12—'True'-temperature/drawing-load curves for mild steel *O*, using Germ R.O.D.

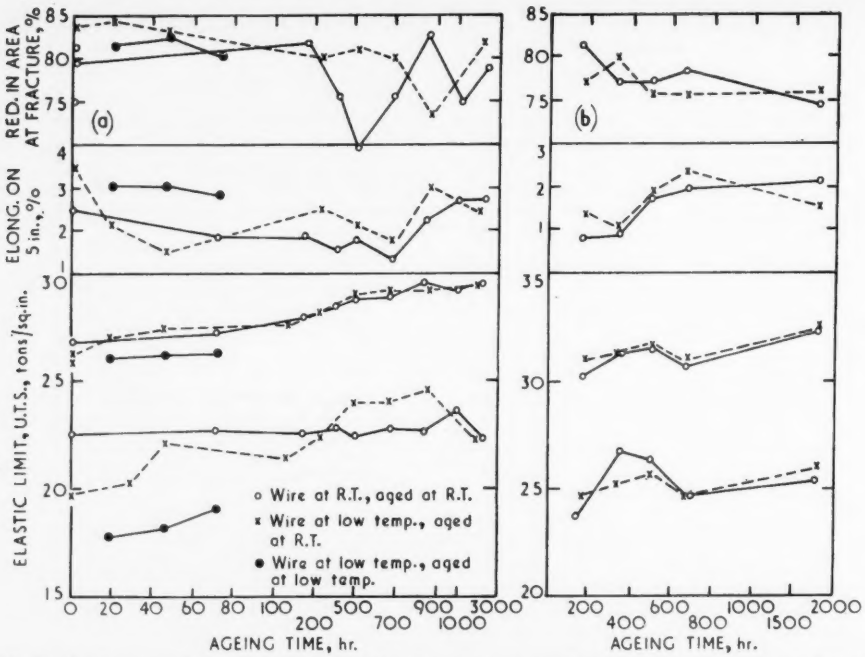

RED. IN AREA AT FRACTURE, %
ELONG. ON 5 in., %
ELASTIC LIMIT, U.T.S., tons/sq.in.
(a)
(b)
o Wire at R.T., aged at R.T.
x Wire at low temp., aged at R.T.
• Wire at low temp., aged at low temp.
AGEING TIME, hr.
AGEING TIME, hr.

Fig. 13—Mechanical properties of steel *O*, with die at room temperature and wire at room or low (−69° C.) temperature, using 'oildag' aged at room temperature. Reduction in area: (*a*) 26·04%, (*b*) 39·16%

of cooling will be necessary, by passing the wire through, say, a trough of liquid air before drawing.

Influence of Low Drawing Temperature upon Mechanical Properties—The mechanical tests were carried out, as before, on a Hounsfield tensometer, but the elongation was measured on a 5-in. gauge length, marked very faintly on the test piece. The change of length was measured by a travelling microscope after the two portions of the fractured test piece had been carefully placed together in a jig. The

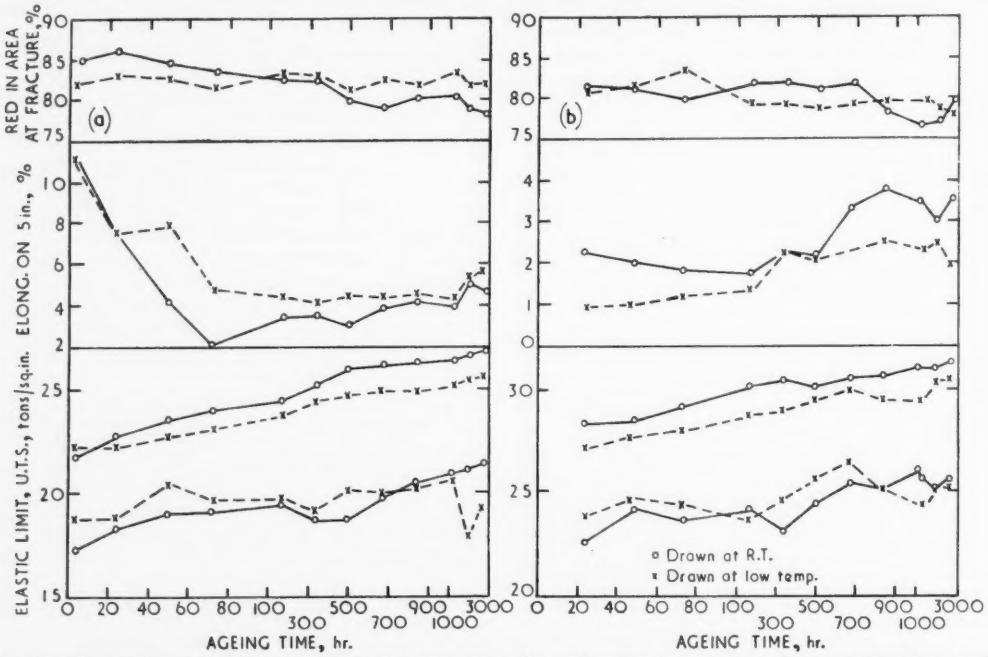


Fig. 14—Mechanical properties of steel *O*, with both die and wire at room or low temperature, using soap 3535 aged at room temperature: (*a*) Reduction in area 11·64%, die temp. — 32° C.; (*b*) reduction in area 26·04%, die temp. — 36·5° C.

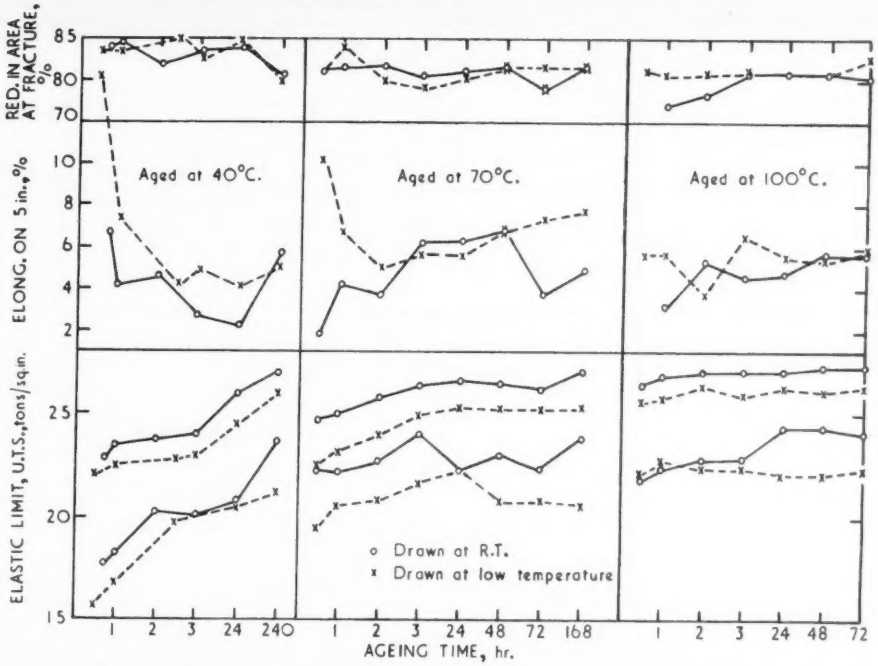

RED. IN AREA AT FRACTURE, %
ELONG. ON 5 in., %
ELASTIC LIMIT, U.T.S., tons/sq. in.
Aged at 40°C.
Aged at 70°C.
Aged at 100°C.
o Drawn at R.T.
x Drawn at low temperature
AGEING TIME, hr.

Fig. 15—Mechanical properties of steel *O*, with both die and wire at room or low (— 37° C.) temperature, using soap 3535. Reduction in area 11·64%

reduction in area was similarly measured under the microscope, four readings of the diameter at 90° to each other being obtained.

Figure 13 shows that there is no very significant difference between the properties of the wires drawn at low temperatures, the die being at room temperature, and those drawn normally, when aged at room temperature for 100 days.

Figure 14 gives the results for the mild-steel wire drawn through the die also at low temperature. The ultimate tensile strength of the wire drawn at about — 35° C. is consistently lower than that for the corresponding wire drawn normally. This applies for both reductions of 11·6 and 26%.

Figure 15 records tests on the same material aged at temperatures slightly above room temperature. The main object was to accelerate the ageing process and thus to obtain stable properties in a much shorter time. With the exception of the elongation of the wire drawn at the low temperature and aged at 70° C. for a week, the properties after ageing at 40° C. for 240 hr., at 70° C. for 168 hr., and at 100° C. for 48 hr., are (within the limit of experimental error) as follows:

Drawing Temp., °C.	Yield Point, tons/sq. in.	U.T.S., tons/sq. in.	Elongation, %	Reduction in Area, %
20	24	27	5·5	80
−35	21	26	6	81

At 70° and 100° C., it also appears that even shorter times of ageing are sufficient to stabilize the properties. On comparison with the values in Fig. 14*a*, for ageing for 3000 hr., very good agreement is found except for the yield point, which is some 2 tons/sq. in. lower after the room-temperature ageing treatment. It appears, therefore, reasonably safe to say that the low-temperature wire for this reduction of 11·6% has a tensile strength about 1 ton/sq. in. lower than that drawn normally; the yield point is some 3 tons/sq. in. lower, and there is no corresponding improvement in the ductility to counterbalance this loss of strength.

Some mechanical properties of the high-carbon steel wires are shown in Fig. 16. As drawn and aged at room temperature, the lowering of the drawing temperature has little consistent effect, but the maximum time of these tests is short, and too much weight should not be placed on the results.

Table V

EFFECT OF DRAWING TEMPERATURE ON WIRE REDUCED IN SEVERAL DRAFTS

Drawing Temp.	Ageing Time (R.T.), hr.	U.T.S. (Tons/sq. in.)	Yield Point (Tons/sq. in.)	Elong. on 5 in., %	Red. in Area, %
Steel *O*, Reduced 0·050 to 0·035 in. in 4 Drafts					
R.T.	1	32·7	29·0	1·1	79·7
	72	33·7	30·2	0·8	77·5
Low temp.	1	32·5	28·2	1·1	81·0
	72	33·2	29·5	1·1	80·0
Steel *L*, Reduced 0·0437 to 0·030 in. in 3 Drafts					
R.T.	¼	99·0	64·0	1·8	57·5
	24	100·0	64·0	1·0	57·5
Low temp.	¼	98·5	63·0	2·0	55·5
	24	98·5	63·0	2·5	59·0

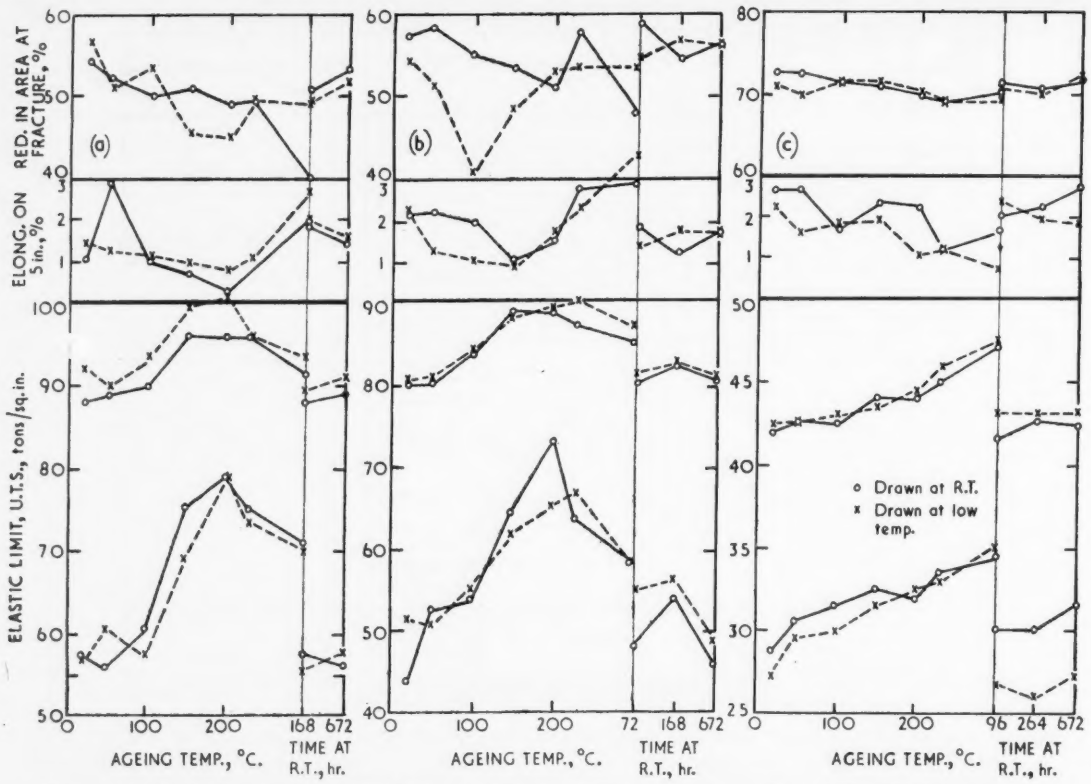


Fig. 16—Mechanical properties of: (*a*) Steel *L*, reduced 20·3% at room and low (— 37·4° C.) temperature; (*b*) steel *B*, reduced 15·2% at room and low (— 31·5° C.) temperature; and (*c*) steel *T*, reduced 22·4% at room and low (— 34° C.) temperature. Lubricant: Germ R.O.D. aged at room temperature and for 1 hr. at temperatures up to 300° C.

The effect of drawing temperature for wire reduced the same amount in one or in several consecutive drafts was similar for both mild steel *O* and high-carbon steel *L* (Table V). No significant differences were observed.

CONCLUSIONS

As the scope of the experiments has been limited, the conclusions are only tentative.

Little difficulty was encountered in drawing mild and carbon steel wires at temperatures down to — 40° C., provided that a suitable lubricant was employed. The most satisfactory means of lubrication appears to be to apply the lubricant at normal temperatures, and then to cool both wire and lubricant together. A firm, adherent coat, resistant to mechanical handling at low temperatures, could be obtained with most of the lubricants employed.

On cooling the wire but not the die, *i.e.*, drawing at about 0° C., the grease-type lubricants and Dag suspensions gave a general fall in drawing load, often quite appreciable, whereas the soaps gave a distinct rise. Although at normal temperatures the soaps were superior, several of the greases were better at the lower temperature. No lubricant, however, gave a lower drawing load than that obtained with the soaps at normal temperatures.

The lowering of the temperature of the whole drawing operation caused an increased drawing load, irrespective of the lubricant, due probably to the overriding influence of the stiffening of the wire. The increase in drawing load for a given temperature fall was of the same order with various lubricants, and the most efficient lubricants at room temperature (the soaps) remained so at the lower temperature. The superiority of the soaps was especially marked at heavier reductions and may be explained in terms of the tendency towards hydrodynamic lubrication exhibited by the soaps, noted elsewhere.[5]

In consequence of the increased drawing load at lower temperatures, it may be expected, and this was confirmed experimentally, that it is not possible to carry out such heavy reductions at the low temperature as are possible at normal temperatures, as the outgoing wire (which soon reverts to normal temperatures) is incapable of supporting the increased load.

Over the temperature range investigated, a lowering of drawing temperature results in no great changes in properties, although certain minor changes, for instance, a slight reduction in the tensile strength of mild steel, were observed.

Bearing in mind the limitations imposed upon the severity of drafting by the lowering of the drawing temperature, perfectly good wire can be produced at temperatures down to at least — 40° C.

Acknowledgments

The thanks of the authors are due to Acheson Colloids, Ltd., the Manchester Oil Refineries, Ltd., and Germ Lubricants, Ltd., for the supply of carefully chosen lubricants; to Rylands Bros., Ltd., for supplying the wire, and to the Drawing Committee of the British Iron and Steel Research Association for useful discussions and financial assistance.

They owe much to the pioneer work of Mr. J. Mickleraith, some of whose results have been incorporated in this paper.

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LETTERS TO THE EDITOR

FATIGUE AND ACICULAR FERRITE IN IRON ALLOYS

The presence of an acicular ferrite has been noted in a boron-treated molybdenum steel when it exists in the normalized condition.[1] To explain the high yield stress of this steel, Allen[2] proposes that as acicular ferrite formed at relatively low temperatures may contain a significant amount of carbon in solid solution, this in itself causes the increase of yield stress. The high endurance ratio (0·6) of this steel, determined independently by a steel company[3] and the author, is, however, important.

Steels or binary iron alloys containing about 8% of nickel also exhibit acicular ferrite, which probably retains more carbon in solution than is usual, since under certain conditions these alloys do not exhibit quench ageing.[4] Such behaviour was not previously expected, since, according to Andrew and Trent,[5] only carbide-forming elements such as molybdenum reduce the quench-ageing tendency of iron; ferrite-forming elements such as silicon and aluminium have been found to be almost without influence. Nickel is generally considered to belong to the group of ferrite-forming elements that have no power to form carbides in the presence of iron. It is, however, important that nickel steels have been shown to exhibit high endurance ratios.[6] Present work substantiates this, and ratios of 0·6 were found.

These are two examples where high endurance ratios are associated with the presence of acicular ferrite. If other examples are found, the explanation for the behaviour will undoubtedly have to await a more complete understanding of the mechanism of strain-hardening and fatigue, and of the phenomena that can take place in the many phases found in iron-based alloys.

The writer's thanks are due to the Chief Scientist, Ministry of Supply, for permission to publish this letter.

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INTERCRYSTALLINE CRACKING OF METALS

The subject of intercrystalline cracking of metals, dealt with by Professor Greenwood,[1] has also been treated by the writer in a recent paper[2] presented before the American Society for Testing Materials in New York. In this paper, time-dependent brittle fracture was conceived to be a process whereby sub-critical microcracks grew eventually to critical size (by Griffith's theory) through random thermal oscillations. Professor Greenwood's description of crack growth by vacancy diffusion seems to be a much better model for brittle fracture.

As well as fracture by this means, Zener's theory of ductile fracture[3] can be noted, as in my paper, where fracture is pictured as occurring after critical-sized microcracks have been formed by condensation of dislocations at some barrier (*e.g.*, grain boundaries). When moved to positions opposite one another, positive and negative line dislocations separated by one plane of atoms will form a crack that is one inter-atomic distance in cross-section.

Finally, Professor Greenwood notes that solute atoms can act as barriers to vacancy migration, and so inhibit cracking. I have suggested[2] that precipitate particles might also act as barriers, both to vacancy and dislocation movement, and thus delay cracking. In my paper, a case is cited in which the formation of a precipitate delayed fracture in an austenitic alloy under test at 1200° F.

It is hoped that these additional remarks will help to stimulate research in fracture, a subject that is receiving much less attention than the phenomena of flow or creep deformation.

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Correspondence on the Paper—

HETEROGENEOUS NUCLEATION OF GRAPHITE IN HYPO-EUTECTOID STEELS*

By W. E. Dennis

Mr. **E. J. Dulis** and Mr. **G. V. Smith** (United States Steel Company) wrote: The author apparently was not aware of a publication[1]† concerning this subject in which it was shown that metallic aluminium rather than aluminium oxide or aluminium nitride was effective in promoting graphitization, either through its scavenging effect for nitrogen, assumed to be a carbide stabilizer, or by some more direct, though unknown, mechanism. A comprehensive investigation was made of the effects of various atmospheres during austenitizing and graphitizing that were believed to be pertinent to graphitization, and the results of that work leave most of Mr. Dennis's interpretations open to question. Rather than go into detail in discussing the experimental results and interpretations offered by Mr. Dennis, it will suffice to examine the main thesis of the paper, *i.e.*, that aluminium oxide serves as the nucleus for graphitization.

The formation of nuclei for graphitization well within the steel by internal oxidation at 600° C., whereby diffusing oxygen combines with aluminium in solution to form aluminium oxide, appears to be very unlikely. According to Darken,[2] the penetration inward or outward, or thickness X of subscale, may be expressed by:

$$X = \left[2D_0\frac{U_0^\circ}{U_0}t\right]^{\frac{1}{2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where

X = depth of penetration, cm.
D_0 = diffusion coefficient of oxygen in steel, sq.cm./sec.
U_0° = solubility of oxygen in steel. wt.-%
U_0 = mean concentration of oxygen in subscale; for Al_2O_3 this would be $\frac{1}{2}U_0^\circ + \frac{48}{54} \times$ wt.-% Al in steel
t = time, sec.

It is apparent that penetration increases with increasing solubility and diffusivity of oxygen. Solubility of oxygen in solid iron has been reported to be less than 0·01% at 800–1000° C.,[3] 0·003–0·006% at 'low temperature,'[4] and approximately 0·001% at 1000° C.[5]; diffusivity of oxygen in iron has been reported to be $7{\cdot}5 \times 10^{-10}$ at 1000° C.,[6] and 10×10^{-10} at 1100° C.,[7] and would be appreciably less at the author's temperature, 600° C.‡ The low oxygen solubility and diffusivity and the presence of considerable aluminium (and also silicon) would appear to make subscale penetration practically negligible, even at the longest test times of less than 2000 hr. at a temperature of 600° C.

For example, using the data of Brower, Larsen, and Shenk[7] the average diffusivity–solubility product $D_0U_0^\circ$, equation (1), was found to be $D_0U_0^\circ = 3{\cdot}3 \times 10^{-11}$ at 1100° C. Assuming the oxygen content (%) of the subscale used in the present investigation to be equal to the aluminium content, the total oxygen is 0·15%. Employing these values in equation (1), it is found that for 2000 hr. at 1100° C. the penetration would be 0·022 in. Extrapolating the temperature–penetration data of Larsen and Brower,[8] the penetration at 600° C. would be expected to be only 0·044 times as much as that at 1100° C., *i.e.*, in the present case at 600° C., a penetration of $9{\cdot}7 \times 10^{-4}$ in. These data are for steel in the austenitic condition, and whereas the behaviour in the ferritic condition would be expected to be rather different, owing to different and unknown solubility and diffusivity, penetrations of up to $\frac{3}{16}$ in. in 1000 hr., as required by Dennis's hypothesis, do not appear to be possible. Another important consideration concerning subscale oxygen penetration in the present case is the large amount of silicon (0·23–0·25%) in the steel, which would be even more effective than aluminium in retarding penetration.

AUTHOR'S REPLY

Mr. **Dennis** wrote in reply: I am in complete agreement with Mr. Dulis and Mr. Smith that no oxide subscale could penetrate to a significant depth in these steels after 1000 hr. at 600° C. However, my hypothesis, to which they refer, requires only that a very small number of oxygen atoms should be able to penetrate along the ferritic grain boundaries by the process of grain-boundary diffusion.

In the conclusion to my paper I stated that " Graphite nodules were found exclusively in the ferritic grain boundaries, where diffusion of oxygen should most readily occur." A survey of the very numerous photomicrographs published in connection with this problem shows this to be a general feature. Furthermore, it has been shown[10,11] that grain-boundary diffusion can occur as much as 100 times more readily than diffusion through the grains of a metal.

This point was not sufficiently emphasized in my paper, and the unqualified use of the term 'internal oxidation' was unfortunate; I am therefore indebted to the contributors for having raised this point. Their own work to which they refer, being mainly concerned with the phenomenon of a 'graphite-free periphery,' does not seem to form an adequate basis on which to postulate even a 'direct though unknown process' for the overall process of accelerated graphitization in these steels.

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* *J. Iron Steel Inst.*, 1952, vol. 171, pp. 59–63.

† Mr. Dennis's manuscript was submitted to the Institute in April, 1951.

‡ The magnitudes of these constants are significantly smaller than in the case of copper. which was studied by Rhines,[9] whose work presumably prompted Dennis's hypothesis.

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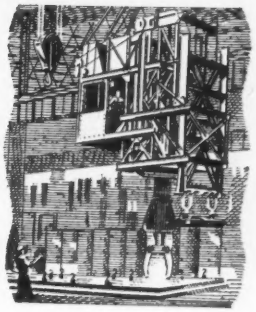

Crane Controls for Iron and Steel Works

By

L. N. Bramley, Ph.D.(Eng.), M.Sc.(Eng.), M.I.E.E.

Part I—MODERN DEVELOPMENTS IN MASTER CONTROLLERS

SYNOPSIS

This paper deals with master controllers for use in steelworks crane cabs and control pulpits. After an examination of the limitations in the operation of present-day cranes, the basic requirements of master controllers for steelworks use are laid down, and it is shown that these can be met only partially by existing controllers.

A new B.I.S.R.A. four-start controller is described; this design is the only one that can meet all, or practically all, the defined requirements. The novel features of three prototype controllers are described, and an interim report is given on trials in steelworks. In general, performance has been satisfactory, although minor teething troubles have been encountered, and the new four-start design has been received with favour. 708

Introduction

During the preparation of the "Specification for Heavy Duty Electric Overhead Travelling Cranes for Use in Iron and Steelworks,"[1] many cranes of various types were inspected to study, at first hand, the control facilities and the working conditions of the drivers. As a result, the following faults in the lay-out of crane cabs, still being perpetuated to a large extent in present-day designs, became apparent.

(i) Controllers are often placed directly in front of the driver, and between him and the side of the cab adjacent to the hook. This means that he must stand at his work, or even lean out of the cab; if he sits down, his lower field of view is severely restricted.

(ii) Visibility is often further limited by steel sections or plates forming the walls of the cab.

(iii) Seats are seldom provided, and when they are, they are unsuitable.

(iv) Controllers are bulky, and their handles, which are generally quite large, usually operate in wide arcs in a horizontal plane. There must therefore be wide spacing between controllers to prevent interference between the handles. One partial solution to this problem is described in the paper, but no completely satisfactory arrangement of the controls of a fast six- or seven-motion crane has yet appeared. Wide spacing causes loss of speed, and efforts to make this good by the operator appreciably increase the physical demands upon him. In a crane of this type, these demands are a limiting feature in materials handling, so that they must be reduced in future designs of cab.

(v) In view of the large sizes of master controllers in use and the multiplicity of connections to them, it is necessary to carry out maintenance *in situ*, very often in dark and inaccessible situations, which would militate against any closer grouping of the controls, even if handle interference were not a limiting feature.

(vi) The wide angles of operation of modern controllers make it difficult to combine two controllers in a single 'joystick' control or to allow foot operation.

There are several other limitations, and all, or nearly all, exist because the controller has always been designed as a unit on its own and then fitted

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Dr. Bramley is Head of the Electrical Engineering Section of the Division.

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in at the control point. A main object of this paper is to show that it should be designed as an integrated control unit.

Consideration of only those faults listed shows that there is marked room for improvement, and there is little doubt that the study of operator comfort and the careful design of controls and layouts will improve speed and precision of operation, and give easier maintenance and lowered accident rates. A serious attempt has been made in the new B.I.S.R.A. crane specification to implement these principles in crane-cab design.

BASIC REQUIREMENTS OF A MASTER CONTROLLER

Arc of Handle Movement, and Orientation and Length of Controller Axis

A principal reason for the large amount of space occupied by the master controllers in steelworks crane cabs is the need to space the controllers so as to prevent interference between the arcs of movement of the handles, and to permit maintenance of the controller interiors *in situ*. Drivers prefer to have a handle of reasonable length and mass, so that they can use its inertia to throw it into the end notches, thus facilitating the rapid working of several motions at once. Little will therefore be gained in orientation of controls by reducing the bulk of the controller itself so long as the handles are operated in wide arcs in the horizontal plane; this mode of movement and the alternatives must therefore be examined in some detail.

All controller handles move in circular arcs, but there is a large difference between wide-angle movements of, say, 130–320° and acute angles of 60–80°. It is a disadvantage of the wide-angle movement used on most modern British crane controllers that, whatever plane it is arranged in, the direction of motion of the operator's hand varies widely during operation of the controller: *i.e.*, the control is not moved in the direction of motion required. This preoccupation with the direction of the controller means that other demands on the driver—speed, accuracy, and safety—all accordingly suffer to some extent.

In the case of controller handles operating over a wide angle, the motion of the operator's hand undergoes a fundamental change if the plane of operation is moved from the vertical to the horizontal. In the first case, the forearm movement is a fairly complicated backwards-and-forwards movement with a change of horizontal direction, but in the second it is simpler—either forwards or backwards. According to Bartlett,[2] hand movements in the horizontal plane are smoother, less tiring, and more accurate than movements in the vertical plane. This is borne out by the present practice in 'tramway' controllers, which seldom have the handle operating in the vertical plane.

An important simplification occurs when the arc of movement is restricted to an acute angle, since the motion is almost a straight line, irrespective of the plane of movement of the handle. Thus, the controller may be mounted with its axis vertical or horizontal, and a sensibly straight-line movement is preserved. Furthermore, straight-line motion is directional, and can be arranged so that when the operator moves a controller handle in a certain direction, the motion controlled moves in the same direction. The placing of control handles in this way is known as 'realism' in controls, and is an important factor in crane-cab design. The fact that it can be achieved means that controllers with a limited arc of travel have a big advantage over the more orthodox controllers in use today.

This is the extent of the advantage to be gained by narrow-arc operation of the controller if it is mounted with its axis vertical. If, however, this axis is shortened and turned horizontal, and if, in a multiple-control arrangement, the handles are arranged to oscillate about vertical lines, they may be brought much closer together without mutual interference. The directional feature is fully preserved, and the motion of the operator's hand still approximates to movement in the horizontal plane.

To locate the controllers of a six- or seven-motion crane so that the handles are correctly placed for the operator, they should be separated by 6–8 in. To effect this, existing controller axes, with one exception, would need to be reduced to about half their present lengths, and even in this exception, the axis would still need to be shortened. It is not, however, completely suitable for installation in a crane cab in its present form, and has not yet been so applied.

Handle Length

The handle should not be too short, since 'feel' and speed of operation would suffer, but, on the other hand, long handles at a multi-motion control point will lead to too wide spacings of controls and increased physical exertions. Little has been published about this factor. One report by Barnes,[3] which does not, however, take into account the factor of fatigue caused by constant repetition of movements, is of interest. He describes an investigation in which the time taken to move a control handle between two stops and the rate of movement were measured for several subjects. Careful measurements were made of the time taken to get the hand started, the time during which it gathered speed, the time during which it was moving at maximum speed, the time of slowing down, and the time stopped. These measurements were made for three different distances of movement—5, 10, and 15 in.—and the results showed that there was little difference in the total times taken, since the longer movements were made at higher speeds. This investigation shows that shortening controller handles does not give a longer time of operation.

The preponderant factor appears to be the need to reduce physical exertion in using the handles of frequently operated controllers, so that the handles should be short rather than long. They must, however, be clear of the controller bodies, and this can be taken as the limiting feature in deciding handle lengths.

Handle Pressure

Usage has shown that the 'feel' of the controller handle is important. The motion should not feel harsh, but should be fairly light; it must, however, have a positive locating mechanism defining the notches. According to Bartlett, " with a joystick type

of control used under bumpy or jolting conditions, a frictional resistance of about two pounds will ensure the greatest precision of movement." A controller handle is not necessarily a joystick, and great precision is not required, but nevertheless the observation is partly relevant; the forces required on some controllers need to be examined in the light of this assertion.

Handles

A 'sword-type' handle on a controller entails considerable wrist motion as it moves in an arc, since it changes in direction while in the hand. The handle should end in a knob that can be held quite loosely in the closed hand with the palm downwards. With a small arc of movement, wrist action becomes negligible.

Domination of the Rotor Position by the Locator Mechanism

There are two factors tending to stop the rotor of a controller in a given position. The first of these is the locator mechanism, whose function is to stop the rotor at a correct position with each contact either fully open or fully closed. The second factor is that connected with the cams or fingers themselves. The contacts are sprung together, so that when the rotor has left a located position, it has to exert a force on the contact fingers or cam followers. If the contact springing is too stiff and the locator mechanism is too light, it will be possible for the rotor to stop with some contacts just opened or not fully opened. With, say, a direct current of 0·5 amp. in the contactor circuit, contact burning will inevitably occur. The location of the rotor must, therefore, be dominated by the locator mechanism, so that it can only stop with each contact either fully open or fully closed.

Cam and Cam-Follower Assembly

Closely associated with the design of the locator arrangements are the cam details, which comprise the peripheral travel between adjacent notches on the controller, the amount of cam lift, and the diameter of the cam follower wheel. These must all be chosen so that where the pair of contacts is to be opened or closed between two adjacent notches of the controller, the cam must displace the cam follower quickly, so that it is either right up or right down at each of the notches. The fact that switchgear is normally assembled to comparatively wide limits means that these dimensions must be carefully designed and the diameter of the cam not unduly reduced.

Other Dimensions, Creepage Distances, and Dust-Tightness

Apart from the vital length dimension of the controller axis and the handle length, the bulk of the controller should be reduced as much as possible. The principal limitation, however, to a drastic overall reduction in master-controller dimensions is that this might lead to the reduction of electrical creepage distances below the safe working limit. Under present conditions, this could be serious, since insulation failure by tracking still occurs.

Tracking is the formation of carbon conducting-paths on or near the surface of certain insulating materials, and a recent survey of papers dealing with the subject[4] shows that it is caused by tangential electrical stress, or by a flashover or sparkover across the insulating surface. Its occurrence is increased by the presence of dirt, conducting particles, or moisture, or a combination of these, on the surface of the insulator, and the damage occurs gradually and eventually leads to breakdown.

Master controllers in steelworks experience high transient voltages during switching, and often operate under dirty or damp conditions, so that the possibility of trouble from this cause must not be neglected.

Several expedients have been tried on contactor switchgear to suppress tracking, but the best method of prevention has been to keep tracking distances long by keeping dimensions large, and to use a well-fitting cover to the controller.

British Standards Specification 587[5] lays down a guide to the minimum creepage and clearance distances for given electrical conditions and, in general, these figures have proved to be adequate for steelworks applications. In fact, master-controller manufacturers have tended to interpret the specification liberally.

Robustness and Wearing Qualities

The controller should be robust to withstand the continuous arduous duty in steelworks. It should be designed with adequate sections on the working parts, and, in particular, the handles and stops must be capable of withstanding forces exceeding those needed to operate the controller. A controller should also be hard wearing. Oil-impregnated metal should be used for the main bearings of the central spindle, but smaller bearings, such as the cam-follower spindles and contact push-rods, may consist of steel pins working in insulating material, since these need no lubrication.

Particular care to avoid undue wear is necessary in designing the locator mechanism. This should err on the large side, and it is a good plan to arrange for it to be external to the controller.

Ease of Inspection

Controllers should be capable of being readily inspected in the crane cab for the diagnosis of the trouble or for a maintenance check. This should be possible merely by removing the cover, which should be clipped, not screwed, and should be free from unnecessary projections and sharp corners.

Ease of Maintenance

Maintenance is not often required on a controller, but any fault must, in most cases, be rectified quickly. The controller, or certain parts of it, should therefore be readily removable and interchangeable on site with spare controllers or parts, but so that the base mounting and all the wiring are left undisturbed.

The actual provision of this facility is, however, not easy. There would appear to be three possibilities:

(i) To make the upper part of the controller and the rotor removable, and so give easy access to the contacts carrying the connections

(ii) To use a fixed contact strip to carry the wiring, and to equip the cam follower and contact assembly, made removable, with spring plungers

(iii) To fit a plug-and-socket arrangement to the base of the controller.

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The first is already incorporated in one production controller, and several worthwhile variations can be envisaged. The second, or some modification of it, is, however, the most promising of the three. The plug-and-socket idea is impracticable, since a very large device would be needed to take care of transient voltages.

Major Repairs

Defective controllers or parts replaced on the crane should be repaired in a workshop where all facilities are available. That speed of repair is no longer vital will also be a factor ensuring a first-class repair.

Standardization of Circuits

Controller circuits should be standardized so that the number of spare parts or units to be carried is minimized. It should be possible to cover 95% of crane-controller requirements in a steelworks with three standard controllers, one arranged for travel-motion duty and the other two for hoists.

Many of the above criteria were laid down originally from commonsense principles after a comprehensive survey of present steelworks controllers and crane cabs. Several are covered briefly in the B.I.S.R.A. crane specification[1] (*see* clause 168 on 'Controllers'), but nothing is included that would limit the crane manufacturer to any one type of controller.

Before dealing with the possibility of designing a controller completely in accordance with the principles defined in this paper, the types of controller available today and the extent to which they embody these principles must be considered.

POSSIBILITIES WITH PRODUCTION CRANE CONTROLLERS

Drum Controllers

Before contactor systems were used for crane control, direct switching of the mains supply to the crane motors was necessary; this was done by the drum-type controller, of which many examples are still in use.

Drum controllers have a central spindle carrying a cast metal spider, on which are mounted copper segments. These moving segments make contact with spring-loaded contacts fixed to the body of the controller. Because of the heavy currents involved, a large volume of copper is needed, which requires a correspondingly robust, and therefore bulky, supporting structure. Modern designs, as shown in Fig. 1, have now reached the limiting size.

In the United States, the drum controller is now practically obsolete for new steelworks cranes; contactor control is usually necessary for hoists at least, since the motors are large, and it is preferred not to mix drum and master controllers in the same cab. There is a more economical attitude towards first cost in this country, and the cross-travel motion controlled by drum is still common. Support for the American attitude is shown in the B.I.S.R.A. specification, which makes it mandatory to provide automatic limiting of acceleration (involving contactor control) for the control of all crane motions or for none of them.

For 3-motion cranes, there is still a limited field for the drum controller, but all-contactor control is in general desirable for heavy-duty steelworks cranes. With more than three motions, there will be no room for the drum controller, and all-contactor control is virtually mandatory. For these reasons, the possibilities of the drum controller do not merit further consideration in this paper.

Drum Master Controllers

When contactor systems were first introduced for crane control, switching requirements were met by using the smallest existing drum controllers as master controllers. Since the magnitude of currents to be switched was greatly reduced (from 75 amp. to less than 1 amp.), the next step was to produce a smaller drum master controller. Any reduction in size due to the lower current rating was largely offset, however, by the fact that circuits of increased inductance (*i.e.*, those of the contactor operating coils) had to be switched. This meant having large clearances to avoid transient effects and tracking, so that drum master controllers were not much smaller than the smallest drum controllers. One manufacturer, in fact, still uses the smallest size of drum controller as a drum master controller. Examples of drum master controllers are shown in Fig. 2.

Cam-Operated Master Controllers for Cranes and Mill Pulpits

Controllers and master controllers of the drum type are basically single-pole switches. Modern control circuits, however, demand the flexibility of double-pole switching arrangements; in addition, troubles were originally encountered with the single-pole drum master controllers owing to the 'sticking-in' of contactors caused by leakage currents on earthed systems.

To meet the consequent demand for double-pole switching, the cam-operated master controller was developed. It has a central spindle carrying cams made from moulded insulating material or mild-steel stampings. These cams, which may be single- or double-start, actuate contactor-type fingers by means of a follower mechanism. The contacts, usually of silver, are mounted on the fingers and make contact with silver or silver-on-brass contacts mounted on the stationary part of the controller.

The controller may be mounted with the plane of operation of the handle either horizontal or vertical, although in most cases it is mounted horizontally, so as to give movement similar to that obtained with drum or 'tramway' controllers. Movement of the handle is circular, and generally covers a wide angle (130–320°).

The cam-type master controller, although a big advance on the drum type, since the rotor carries no current, does not show an appreciable reduction in size, and is not of a shape that lends itself to close grouping of controls. However, it is in wide use in the steel industry and, within its limitations, is giving excellent service.

Cam-operated controllers for cranes produced in Great Britain may be classified into those having single-start and double-start cams respectively. A double-start cam controller is one that operates two contact assemblies in the plane of one cam circle. Each contact assembly has its own follower, and both followers bear on diametrically opposite points of the cam circle mounted on the central spindle.

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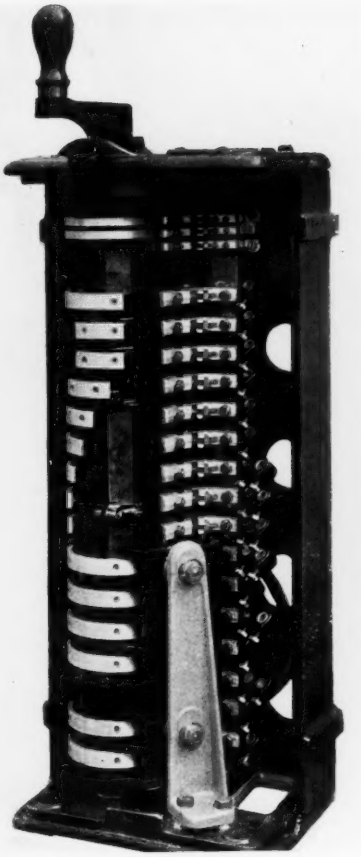
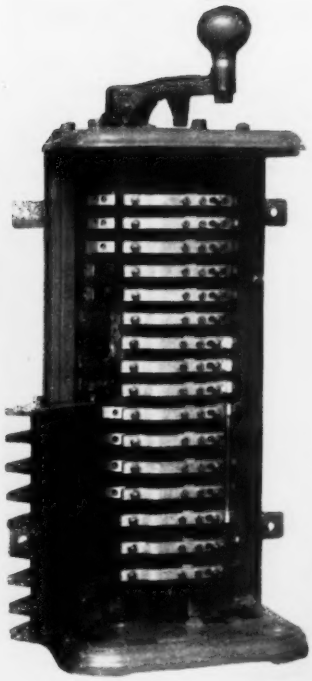
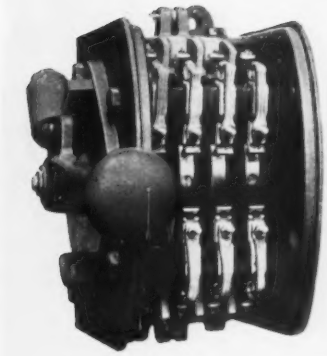


Fig. 1—Drum controller



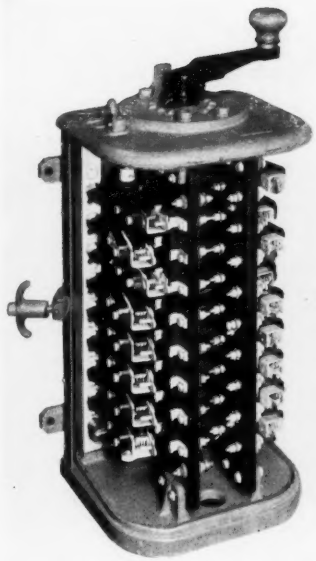
(a)



(b)

(c)

Fig. 2—Drum master controllers



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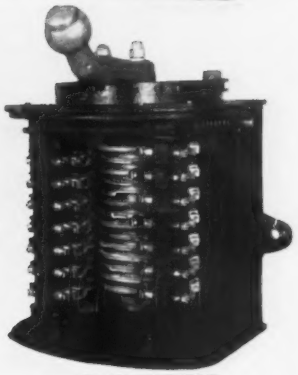

(d)

Fig. 3—Cam-operated master controllers for cranes

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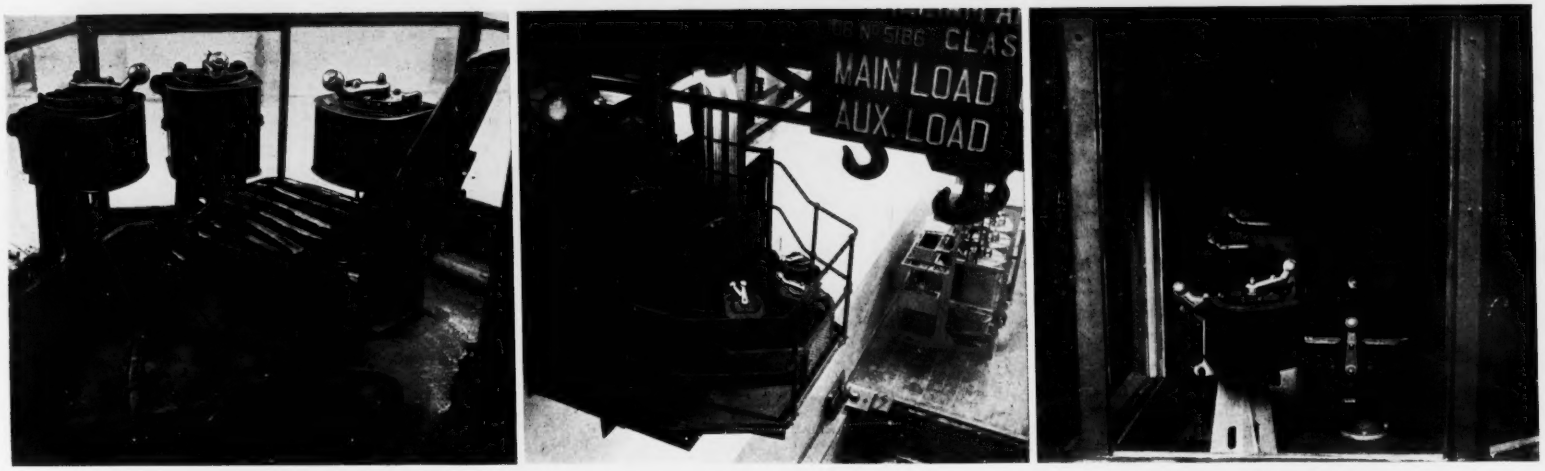

(a) (b) (c)

Fig. 4—Crane cabs showing modern arrangements of master controllers : (*a*) 3 controllers ; (*b*) 4 controllers with one pair arranged for close spacing ; (*c*) 6 controllers with 2 pairs arranged for close spacing and 2 controllers under the seat

(a) (b) (c)

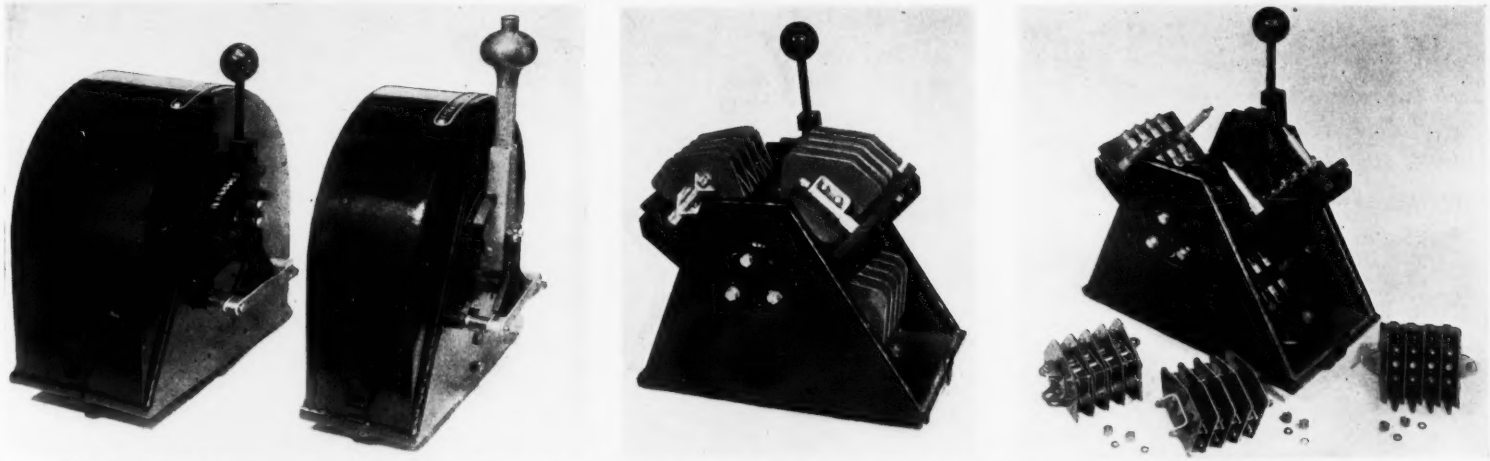

Fig. 5—Four-start cam-operated hoist and long-travel controllers (design *D*) : (*a*) Exteriors ; (*b*) top cover removed from hoist controller ; (*c*) contact assemblies of hoist controllers, dismantled for servicing

(a) (b) (c)

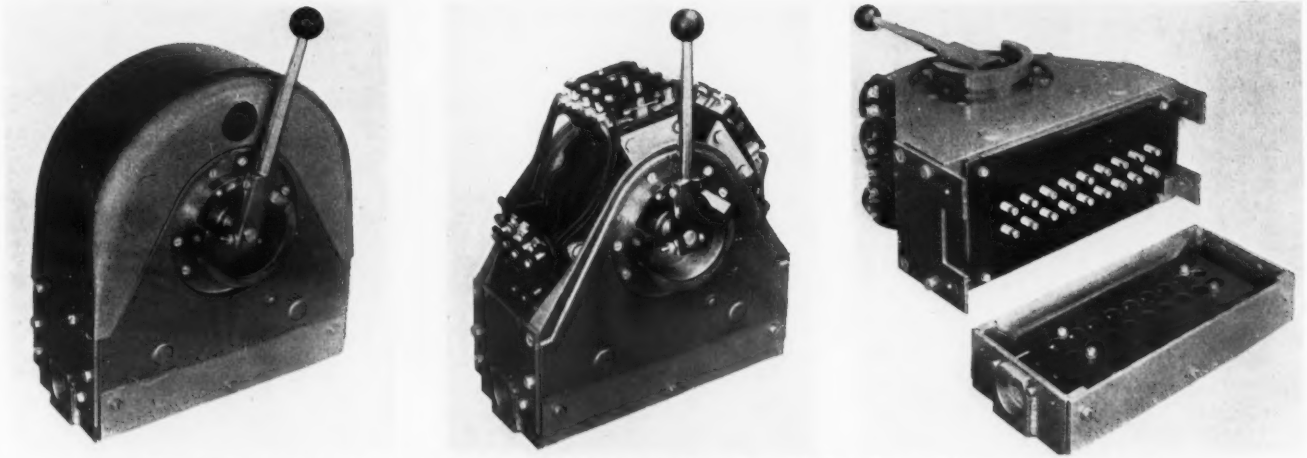

Fig. 6—Four-start cam-operated hoist controller (design *E*) : (*a*) Exterior ; (*b*) top cover removed ; (*c*) upper unit removed for servicing

(a) (b)

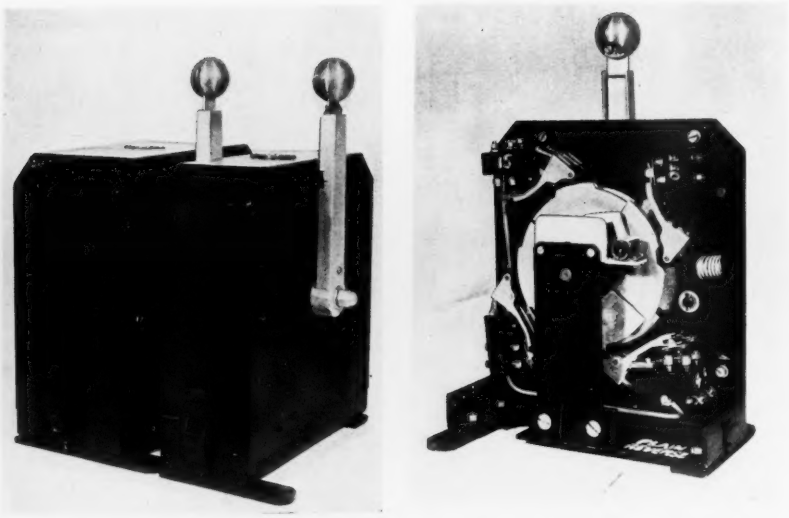

Fig. 7—Four-start cam-operated hoist and long-travel controllers (design *F*) : (*a*) Exteriors, showing grouping ; (*b*) cover removed from travel controller

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To face p. 57]

There is at least one single-start cam-operated production controller in general use on cranes and in mill pulpits (*see* Fig. 3*a*). It is of very robust construction, and is almost always installed on its base with the plane of operation of the handle horizontal.

Another form is shown in Fig. 3*b*, in which a bevel-gear arrangement allows operation of the handle in a vertical plane. Owing to its large gear ratio, it is rather stiff to operate, and it is not used as much as the one described above.

At least one double-start cam-operated controller is also widely used in cranes and mill pulpits (*see* Fig. 3*c*); in this, the cam circle consists of two semi-circles that are slightly staggered along the axis of the controller. This improves production facilities, but it is still a double-start controller, since there are two banks of contacts spaced diametrically around the camshaft. This controller is also very robust.

Modern Arrangements of Cam-Operated Production Master Controllers

Fairly good arrangements are possible with these controllers for cranes with relatively few controls. Figure 4*a* shows a simple 3-controller arrangement, and another application of this type of controller worthy of mention is given in Fig. 4*b*, which shows the cab of a 4-motion crane, recently installed in a large steelworks, that meets some of the disadvantages listed in the Introduction. For instance, the driver has a seat, and visibility is greatly improved. The point of immediate interest is the disposition of a pair of production master controllers arranged back-to-back on one side of the driver. The controller of the pair nearer the driver is orientated normally, but that further from him on the same side is raised about 3 in. and its handle is reversed to bring it within reach. Two handles are thus brought close together without interfering with each other.

This arrangement is an advance on anything yet seen in a crane cab in Great Britain. It has its limitations, however, since accessibility of the further controller cannot be made adequate without considerable enlargement of the cab and some reduction of visibility.

The same company has recently developed this scheme to equip a 6-motion crane cab, but only by placing the two extra controllers under the seat, as shown in Fig. 4*c*. This is not a good arrangement, since it results in wide and unco-ordinated spacing of the handles; moreover, the two controller bodies under the seat are inaccessible, and the seat height cannot be varied.

Cam-Operated Master Controller for Excavators

Another production double-start cam-operated controller, intended for use in mechanical excavators, has been specially designed to improve cab layout, although bulky. It is thus of interest, although not completely suitable for crane-cab use in its present form.

The controller has three double-start cams with four notches forwards and reverse, and an off-position. The handle is designed for operation in the vertical plane, and is equipped with a cylindrical or 'sword-type' handle. The controller is very robust, with a massive cast-iron body.

An important maintenance feature is that it is assembled in two units, and the top unit can be readily unscrewed from the base. All the moving parts are confined to the top unit, and no wiring connections are involved in its removal, so that a complete spare top unit can be substituted in a few minutes. The fixed part of the electrical contacts in the lower unit must be serviced *in situ*, although removal of the upper unit makes the contact plates and wiring very accessible. It is not generally suitable for present-day cranes since it has only six circuits.

This review of the present possibilities of modern cam-operated controllers provides evidence that there is a field of application for a new master controller that lends itself to a more integrated layout. The problem is more urgent for crane cabs than for the steel mill, and its importance increases with the number of motions to be controlled.

POSSIBILITIES WITH NEW CONTROLLERS

Criteria for a Basically New Controller

The key requirements for close grouping of controllers and preservation of direct 'near straight-line' operation are that the controller axis should be short, and that the handle should be arranged to move in a limited arc of movement in a vertical plane on each side of the vertical off-position. Present-day cam-operated controllers can be orientated for vertical handle operation, but they cannot meet the first requirement, so that in a new design the axis must be shortened. This can only be done by reducing the number of cam discs that are arranged side by side. Since the number of circuits cannot always be reduced, there must be more cams per cam disc.

A preliminary investigation showed that this idea was practicable, and criteria based on the requirements already listed were submitted to three of the chief controller manufacturers. It was suggested that each should produce a design such that its basic features could be used for both a hoist controller and a travel-motion controller. The hoist controller was to have sufficient cam wheels, each carrying a minimum of three cams and each actuating the same number of cam follower units, to give at least 14 separate switching circuits, and was to have 12-notch (6–0–5) operation. For the travel controller, the axis length was to be reduced to carry only enough cam wheels to give a minimum of eight circuits, and the angle of travel was to be limited to give 9-notch (4–0–4) operation. The sides and bearings of both long-travel and cross-travel controllers were to be identical and, as far as possible, the contact assemblies actually in use on their production controllers were to be used in the new designs.

New Designs of Four-Start Controllers

Willing co-operation was given by the manufacturers, who all prepared new versions of four-start controllers, following the original criteria laid down but incorporating their own ideas.

Minor modifications to these designs were made in agreement with B.I.S.R.A., and the manufacturers then constructed prototypes.

XUM

Two of the firms produced both a hoist and a travel controller and the third a hoist controller only (shown in Figs. 5–7). Figures 5*a*, 6*a*, and 7*a* show the controllers with the covers on, and in one case show how the handles can be grouped for convenient operation; Figs. 5*b*, 6*b*, and 7*b* show the controllers with the covers removed; and Figs. 5*c* and 6*c* show how a contact bank or the upper part of the controller is removed when contact overhaul or replacement becomes necessary.

The resulting products, although somewhat similar in external appearance, differed appreciably in detail; *e.g.*, the detachability feature, which follows entirely different principles in each controller. It is not visible in Fig. 7, but is provided by incorporating contacts mounted on removable spring steel bows on the ends of the fingers. In Fig. 5, contact assemblies are seen to be removed in banks, and in Fig. 6 the whole upper part of the controller is removable. In none of these controllers need the wiring be disconnected should replacement of removable parts be necessary.

At a later stage in the investigation, the manufacturers agreed to put one of their designs into production, and design *D* was chosen for this purpose.

Design *D*

The design is very compact (*see* Fig. 5); the cover is rounded over its upper surface so as to clear the handle, and is removable, so that all four banks of contacts are revealed. Dust tightness is taken care of by a **V**-channel in the box edge packed with tallow-impregnated rope into which the inverted edge of the cover bites. The cover is kept firmly in place by two toggle clips.

The main bearings, of oil-impregnated metal, are carried on side uprights that form part of the exterior of the controller, and the shaft carries eight or 16 quadrant cams of plasticized fabric arranged as two or four cam wheels respectively. The cam follower wheels and supporting arms are also of plasticized fabric, and separators of the same material are incorporated between circuits.

Features of special interest are the 4-contact bank and cam follower units, which are carried on stationary pillars radially arranged around the camshaft but attached to the main body. As shown in Fig. 5, these pillars each carry one of these units, either 2- or 4-circuit, depending on whether the controller is for travel motion or hoist control. When the banks are fastened into place on the pillars, contact is made *via* two long spring pins for each circuit to corresponding stationary plates bearing the wiring. The circuit is thus brought through the removable unit to the top ends of the pipe. These form the stationary contacts, and are bridged by a sprung contact piece, raised or lowered by the cam-follower arm to make or break the control circuit. All contact surfaces are of solid silver.

The contact banks themselves are held on the pillars by drilled ears, and removal is simply a matter of unscrewing two nuts from the pillar ends and lifting off the bank. Both lower and upper banks are readily visible and accessible when the main cover is removed.

The advantage of this design is that all 2- or 4-contact bank assemblies are interchangeable, since they are quite independent of the circuit of the controller. Thus, if this type of controller is made standard in a steelworks, the maintenance engineer need only carry two contact banks with him on his inspection rounds, one bearing two contacts and the other four. Any contact trouble is then rectified by a change of bank, a matter of seconds. The contact banks weigh only a few ounces.

Wiring entry is by screwed conduit *via* the base, and connections are initially made with the banks removed. All terminals are marked.

The prototype hoist controller, which was completed first, had no positive off-position latch, the off-position being held rather more firmly by a deeper notch in the locator mechanism, which was external. In the travel-motion prototype controller, completed later, a positive latch, operated by a button in the handle, was incorporated, and the whole locator mechanism was mounted internally.

TESTS ON MASTER CONTROLLERS

Arrangement of Test Facilities

At the start of the programme of developing the new 4-start controllers, it was agreed that prototype controllers should be made up to the designs described, and that, if possible, they should be submitted to extended trial under practical conditions in heavy-duty steelworks overhead cranes. After suitable cranes had been chosen in three steelplants, the steel companies sent details of the crane circuits to the controller manufacturers to enable the cam profiles to be designed.

As the prototype controllers were completed, they were installed in the selected cranes and put to work.

Tests on Controllers

All the designs proved successful, although some teething troubles were naturally experienced. They are all still working or temporarily withdrawn for inspection. At present it is intended to end these tests as each controller completes two years' life, when a report on their performance and final condition will be issued.

CONCLUSIONS

(1) Many crane-cab layouts in use today could be greatly improved if the present-day single- and double-start cam-operated controllers were used to their best advantage.

(2) Further improvements, especially in multi-motion crane cabs, are possible with the new B.I.S.R.A. 4-start controller.

(3) Trials still proceeding have shown that the new controllers are basically sound, and are well liked by the operators.

(4) The modern master controller should incorporate the following features:

(i) The camshaft should be short and horizontal

(ii) The handle should be short, and should operate in a vertical plane. A 4-start arrangement of cams should be used to give a small angle of travel of the handle, and thus achieve approximately straight-line control motion

(iii) The ' feel ' of the controller should be smooth and light, and yet be adequately located. The rotor position should be dominated by the locator mechanism

(iv) The handle should end in a control knob rather than a ' sword-type ' handle, and the knob should be securely fixed

(v) The peripheral travel of the cams per notch and the other cam dimensions should be adequate to ensure that, at each notch, each contact is fully open or fully closed. Other controller dimensions should be reduced as much as is consistent with the attainment of adequate electrical creepage distances

(vi) Controllers should be very robust and hard-wearing, and covers should be dust-tight. They should be clipped on, not screwed, and should be free from unnecessary projections and sharp corners. It should be possible to inspect all working parts by removing the cover

(vii) Controllers should be designed so that, when a fault occurs, the upper part of the controller or a contact bank can be immediately replaced by another unit on site, and the faulty part removed to a workshop for repair. Detachability should preferably leave the base unit and wiring undisturbed.

(5) Circuits on cranes should be standardized so that the number of spare controllers or parts is reduced to a minimum.

Acknowledgments

Thanks are due to the three switchgear manufacturers who have co-operated in the design and production of the new 4-start controllers, and in the installation and testing of the prototypes in steelworks cranes. Thanks are also extended to the steelworks managements who are co-operating in the testing of these controllers, and to those steelworks managements and personnel who have furnished illustrations and information for this paper.

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Part II—SUGGESTED CRITERIA FOR THE DESIGN OF CRANE CABS

SYNOPSIS

This second part of the paper deals with the principles of crane-cab design. General design is covered by the new B.I.S.R.A. ' Specification for Heavy Duty Electric Overhead Travelling Cranes for Use in Iron and Steelworks.' The particular aspects of the layout of the control point itself are examined in the light of the new science of ergonomics, which is concerned with the study of the relation between man and his environment. This has a fundamental bearing on the subject, particularly in relation to the seating of the operator, working heights and areas, visibility, realism and pattern of the controls, distribution of controls, and recognition of controller handles. Installation of controls and the orientation of the cab in relation to the crane itself also receive attention. The principles laid down are implemented in suggested designs of control layouts for two multi-motion cranes and a charging machine, all using the new four-start controllers.

The paper concludes with a list of points that still require investigation if master controllers and crane cabs are to be further improved. 708

Introduction

PART I of this paper embodied a comprehensive study of controllers for use in steelworks crane cabs and control pulpits. After drawing attention to present-day limitations in crane operation, the basic requirements of master controllers for steelworks use were laid down; these could be met only in part by existing controllers.

A report was given of the progress to date on a programme of controller improvement embracing a new B.I.S.R.A. design of four-start controller that can meet practically all the defined requirements. The novel features of controllers were described, and an interim report was given on prototypes at present undergoing trials in steelworks.

Part II of the paper deals with the possibilities of designing crane cabs in accordance with scientific principles using the new controllers.

PRINCIPLES OF CRANE-CAB DESIGN

Matching Machine to Operator

Machines can be made more efficient by matching them to their operators. This can be done only by studying the mental and physical characteristics of human beings. Much valuable work has been carried out, largely in the U.S.A. and Great Britain, on this subject, and the data are now largely available for industrial application.[1–4]

The design of controllers and of the crane cabs or other control points that house them are to some extent mutually inclusive. Thus, in Part I, guidance was obtained on improving the master controller by considering how a bank of these would fit together most conveniently for operation, and it is now proposed to examine the problem from the standpoint of the integrated design of crane cabs.

Crane-Cab Design according to the B.I.S.R.A. Specification

When the existing steelworks crane specifications and B.S.S. 466[5] were studied before the present B.I.S.R.A. specification[6] was drafted, it was found that the crane cab was only briefly mentioned. In view of this and the diversity of designs found in the survey of crane cabs, and the many possibilities for improvement, an attempt was made to cover the subject adequately for the first time.

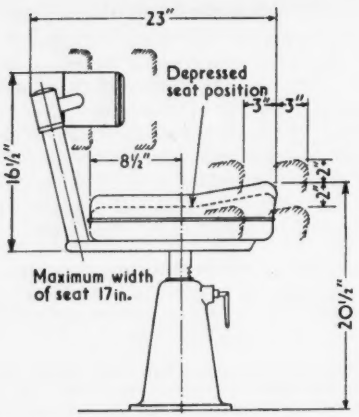

Fig. 8—Anatomical seat: general arrangement

The Cab Seat

One of the most important factors in the design of an efficient cab is a properly designed seat for the driver. As defined in the specification, it must be strong, hard wearing, adjustable, and located near the window through which the driver normally sees his working point,* and it must offer no obstacle to the driver when taking or leaving it. Since the specification was produced, it has become evident also that the seat should be towards the hook side of the cab in some cases so that, without leaving his seat, the operator can lean or look out of a side window and see the hook when the falls are close to the cab.

Much work has been done by the Admiralty in conjunction with the Department of Human Anatomy of the Medical Research Council, Oxford, to determine the correct form for a seat suitable for naval ratings carrying out operational duties on ships. The findings are described by Darcus[7] in a report compiled under the auspices of the Medical Research Council for the Royal Naval Personnel Research Committee. The chief requirements for an ideal seat for use in naval operations are as follows:

(i) It must accommodate individuals of different body dimensions within the 90% range† in the most efficient position
(ii) It must stabilize the body
(iii) It must allow the operator to sit for periods of up to 4 hr. without undue discomfort or fatigue, and must permit an alert and a relaxed position
(iv) It must combine lightness with mechanical efficiency, and withstand very severe usage and weather.

The criteria for crane seats and naval operational seats have much in common. A prototype naval seat, called the 'anatomical seat,' has already been made. This embodies mechanisms of different degrees of complexity, necessary for the exact positioning and efficient stabilization of the naval rating on a moving ship, not all of which are necessary for use in cranes. The rise-and-fall and the backward-and-forward adjustments are all that are needed for a crane-cab seat, and the makers agreed that the upper part of the seat could easily be separated from the lower part and mounted by itself on a conical pedestal. The result is shown in Fig. 13.

The conical support is bolted solidly to the floor, and the rise-and-fall motion of 4 in. is given by a solid steel pillar sliding inside it. The top of the pillar carries a horizontal member on which the base of the seat container can slide backwards and forwards 3 in. each way from the central position. The seat consists of a composite squab of springy aerated plastic, covered with a very strong, wear-resisting material. The squab is thickened at the front to support the lower thighs, and provides a firm yet comfortable seat. Ventilation is provided by recessed seams across the covering.

From the back of the seat container a single central pillar rises, upon which is supported the back-rest, a curved support also upholstered in aerated plastic. It is capable of a limited amount of angular movement about a horizontal line so as to fit the back of almost any operator without any need for up-and-down movement. The back can be rotated through 90° on each side of its natural position on the back pillar to allow access and egress from the seat. It is normally locked centrally. With these adjustments, the height of the seat from the floor to the upper surface of the seat cushion when depressed can be varied from 16½ to 20½ in. (*see* Fig. 8). This should allow most operators to adopt a comfortable position with correct weight distribution.

It is proposed to group the controllers before the driver, conveniently to his hands, but not immediately in front of him, so as to improve visibility from the cab as much as possible. The vertical and horizontal seat adjustment should allow almost any operator to place himself both for comfortable working of the fixed controls and for maximum visibility.

There is a very strong body of opinion in favour of the bucket-type seat as a work seat for a control point. The possibilities of this type of seat have been carefully examined by Darcus, who found it wholly unsatisfactory for naval work. His conclusions also apply largely to seating in steelworks cranes, and it is to be hoped that the bucket seat will be discontinued in crane cabs.

Working Heights and Areas in the Cab

Having arranged for the correct seating of the operator, the controls must be grouped around him so as to achieve the maximum efficiency of working, *i.e.*, to fit the machine to the operator.

The first thing to settle is the height of the controls. Anthropometric data[1, 2, 3] suggest that to enable the operator to use his controls to the best advantage, *i.e.*, with his forearms horizontal or nearly horizontal, the handles should be 9½ in. above the level of the compressed seat cushion with the seat in its highest position. Taking this height as 20½ in., the mean height of the controller knobs should be about 30 in. from the ground. This may be called 'the normal horizontal plane.'

Chapanis, Garner, and Morgan[4] point out that work done with the hands can involve five different parts of the arm: the shoulder, the upper arm, the forearm, the wrist, and the fingers. Work can be classified according to how many of these are used; the more

* Referred to in the paper as "the cab front."
† Comprising 90% of the adult population.

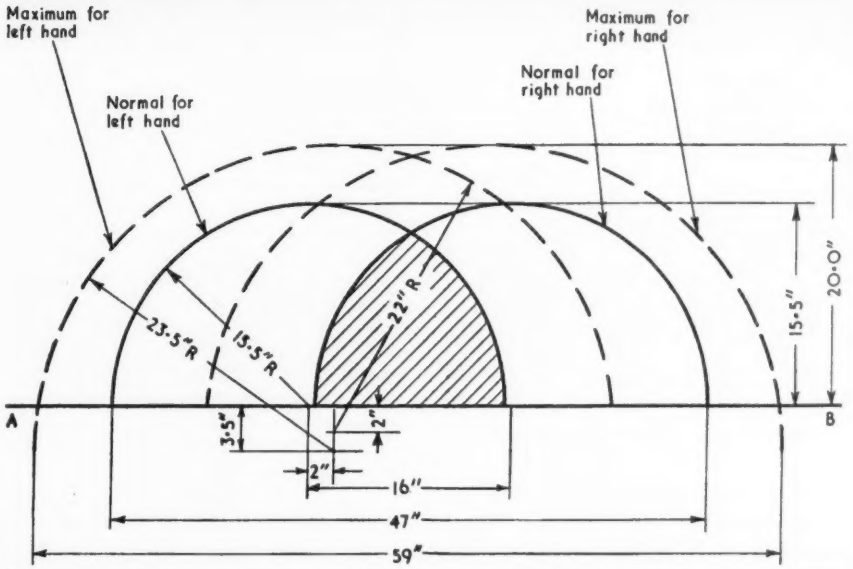

Fig. 9—Normal and maximum working areas on a horizontal surface (after Barnes[8])

classes involved, the more energy expended, and the more time taken. They reproduce a diagram for horizontal areas from a book by Barnes[8] (*see* Fig. 9), showing maximum and normal working areas for each arm. Maximum working areas are those that can be reached without contorting the shoulders and trunk; normal working areas are those that may be reached with movements restricted to the forearm and wrist alone. The measurements given in the diagram are fairly conservative, and should apply to about 95% of the adult population. The shaded area, in which the semicircles for the two arms overlap, represents the positions that can be reached or used normally with either or both hands.

To preserve visibility, and because it is tiring for an operator to raise his arms constantly, controls should not be placed well above the normal horizontal plane. In some cases, however, a comparatively unimportant control may have to be put in such a position, and so some guidance as to the reasonable limits of dimensions to be observed is necessary. Lipschultz and Sandberg[9] have defined these maximum reach distances on a vertical working surface (*see* Fig. 10). The circles are for viewing distances of 10 and 20 in., and are for men with short, medium length, and long arms. To apply these findings to 95% of the population, the smallest or most conservative circles should be used.

Visibility and Seat Position

To ensure maximum visibility for the driver, the B.I.S.R.A. specification provides (clause 165) that no equipment shall be placed immediately in front of him. The limitation here is in the placing of controllers in positions that would interfere with the normal position of the knees. It is reasonable to define a clear section contained by two lines drawn through the sides of the seat (16 in. apart). In a stripper crane, where the operator looks down between his knees, they should be larger.

The seat should be located so that, when the operator is seated, his arms move within the circles prescribed by Barnes. Darcus states that, from a study of anthropometric data and from a knowledge of the dimensions of the anatomical seat (*see* Fig. 8), the centre of the seat pedestal should be 2 in. in front of the straight line bounding the Barnes horizontal working areas (*AB* in Fig. 9).

The cab front must be far enough from the seat to allow comfortable clearance for the feet. Darcus[7] states that the minimum distance between the front wall and the front of the seat in its most forward position should be 12 in., so that the cab front must be a minimum of 24 in. in front of the centre of the seat pedestal.

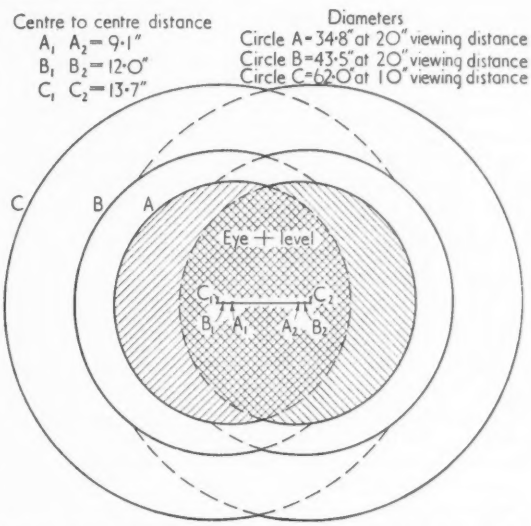

Fig. 10—Maximum reach on a vertical working surface for different operators (after Lipschultz and Sandberg[9])

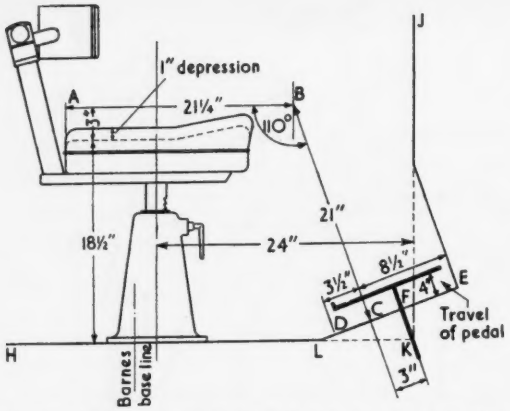

Fig. 11—Anthropometric data for foot controls (after Darcus[7])

When foot controls are used, the dimensions must be extended, and the arrangement shown in Fig. 11 has been suggested by Darcus. The suggestion that the foot pedals *F* should be flush with the floor in the undepressed position has not found general favour, and so it is now recommended that the pedals, which should accommodate the major part of the foot as shown, should stand 4 in. above the floor when not depressed. Pedals should be arranged to the sides of the central floorboard so that the foot is moved sideways to operate the pedal. The provision of foot pedals means that only a slight bulge in the front of the cab is necessary, which will not interfere with visibility.

No definite ruling can be given about the distance of the cab front from the operator at controller level. The specification states that it should be as close to the driver as possible since, when he is looking down at a steep angle, *e.g.*, in ingot-handling cranes, the closer he is to the cab front, the better is his view. In this type of crane, however, the driver will generally see his working point through a floor panel, and so it is not so important to bring the cab front close to the controllers. It may be advantageous to situate it further from him and bring the glass of the cab front down to meet the floor panel, which can also be of glass. This will not decrease visibility if the partition member at the point of intersection of the two surfaces is kept narrow, and it is simple to provide a foot guard for the lower glass panels.

Visibility towards the front should in general be limited solely by the controller bodies themselves, and not by any steel plates forming the lower enclosing walls of the cab. These should be low or should be replaced by glass panels.

The front glass panels should not be closer than 4 in. to the back of the controller covers, to allow adequate facilities for inspection and light maintenance of the controllers *in situ*. This will also facilitate cleaning of the cab, and prevent the driver from barking his knuckles when pushing controls fully forward.

One poor design feature still to be seen in modern crane cabs is the use of wide corner posts. No vertical member between the operator's eyes and his working area should be wider than 2 in., so that the cone of obscuration points away from the operator and disappears before reaching the ground or the hook. Using members only slightly wider than this means that large areas on the shop floor are out of view unless the operator moves appreciably. When the travel motions are in use the operator must be able to see over a wide area, for safety and also to enable him to plan his movements with precision.

In spite of these obvious and easily attained requirements, cabs are still being built with extensive opaque areas in the front and sides. This point is dealt with in the B.I.S.R.A. specification.

Most of the dimensions laid down above are worked out from recorded data, but, at least in the early stages of its application, a full-size model should be constructed and trials made, with operators varying in size over normal limits, to check the positions of all the control handles in relation to the seat.

Direction of Motion of Controls

Little or no information is available about the effect of direction of motion of a control, relative to the body, on speed. Straight-line control motions in the horizontal plane may be broadly classified into radial motions from the shoulder or elbow points, and circumferential motions. Both are used, but the former are more common—*e.g.*, car brake levers and aircraft throttle controls.

If straight-line controls are to be arranged within the Barnes working areas, there are broadly two arrangements possible. One is shown in Fig. 12*a*, in which the directions are more radial than circumferential, and one in Fig. 12*b*, in which the directions are more circumferential than radial. The former is more natural, and will probably give higher speeds of operation.

Realism in Controls

The use of realism (arranging controls to move in the direction of the motion controlled) is important in designing control layouts, and is already adopted in steelworks cranes to some extent. Thus, in some

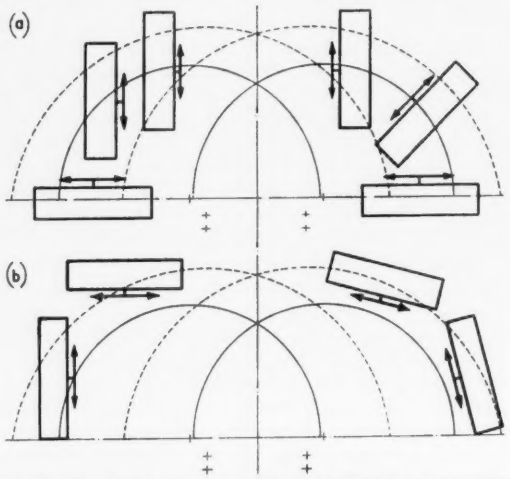

Fig. 12—Possible arrangements of straight-line controls in the horizontal plane: (*a*) More radial than circumferential; (*b*) more circumferential than radial

(a) (b)

Fig. 13—Anatomical seat developed by the Department of Human Anatomy for operational use in the Royal Navy. Simplified form for crane use : (*a*) In lowest position ; (*b*) raised, showing rise-and-fall and forwards-and-backwards mechanisms

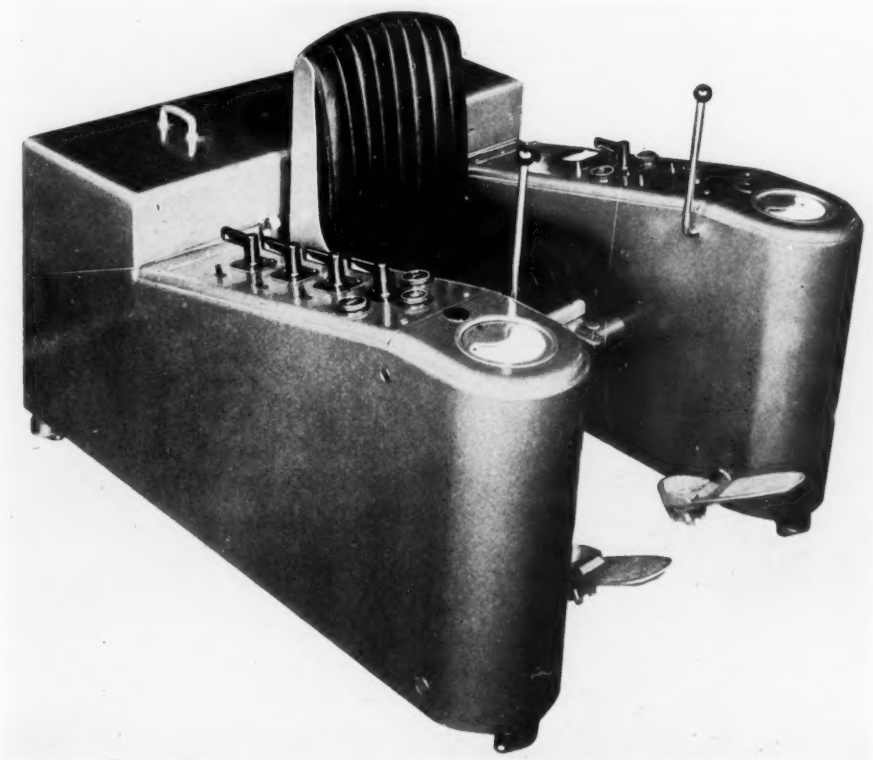

Fig. 14*a*—Foot controls in a 20-cu. yd. walking drag-line, controlling the slewing motion

[*Bramley*

[*To face p.* 62

Fig. 14*b*—Foot controls in a modern slabbing mill, controlling several motions

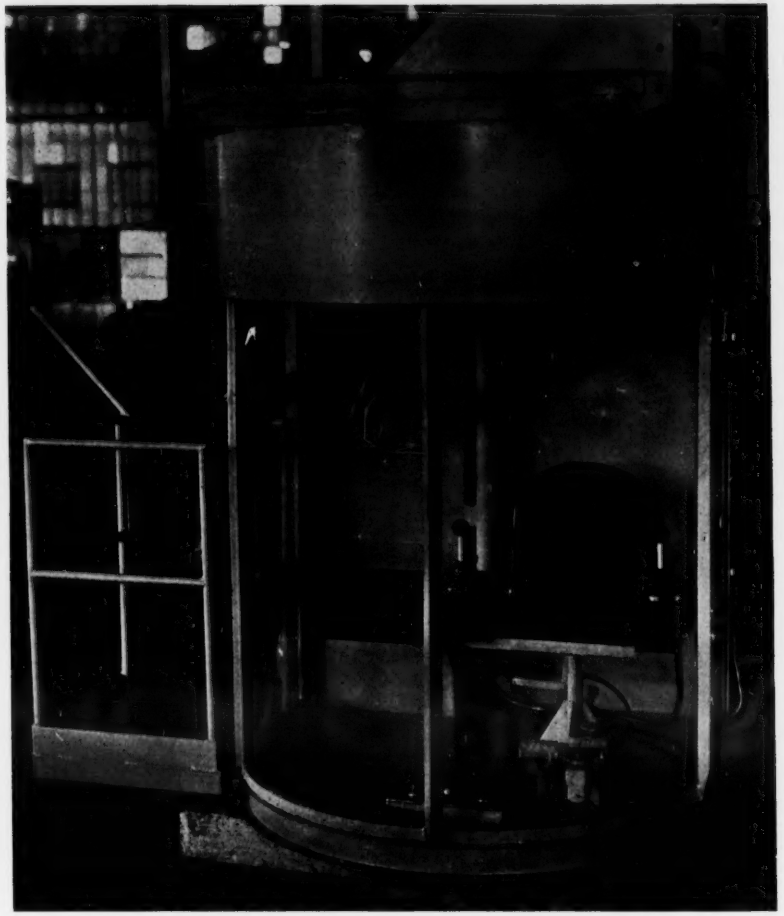

Fig. 15—Layout of controls in an American crane cab

cranes the travel motion controllers are so arranged that when they are moved from the off-position, the crane or cab moves in the same direction. Movement at the ends of the arc has no realism with conventional controllers. A few cranes have the two main travel motion controllers arranged with their axes horizontal and at right-angles, and the handles are combined in a kind of 'joystick.' Here the crane moves in the direction of motion of the joystick. Such combined motions are rare in steelworks cranes, but the principle is popular with operators.

In every such arrangement that the author has seen, the 'feel' of the joystick was bad because the mechanical movement was generally too stiff for smooth operation, and the wide arc of total movement of the controllers either resulted in too large a displacement of the joystick handle or in too short a stick. A short travel of the handle per notch and a restricted arc of total travel are required for this method of combining motions, and these were contributory factors in the formulation of the design of the four-start master controllers.

Chapanis, Garner, and Morgan[4] cite experiments by themselves and several others to support what they call the 'commonsense rule' that a control should move in the same direction as the part controlled. Realism is not essential in all controls. It is easier to learn to use a control when both hand and machine movement are in the same direction, but operators can learn to operate controls lacking realism if given sufficient training. A reasonable compromise is attainable by adopting the following principles in crane-cab design:

(i) Lines of motion of controller handles should be horizontal or approximately horizontal
(ii) Hoist controls should have the lines of operation of their handles pointing in the direction of the hoist motion. Forward movement of the handle should be used for lowering, and backward movement for hoisting
(iii) The direction of operation of the cross-travel motion controller should be across the gantry, *i.e.*, parallel to the cross-travel motion
(iv) The direction of operation of the long-travel motion controller should be parallel to the crane gantry
(v) Items (iii) and (iv) should be combined in joystick control where possible
(vi) Other controls should be installed in accordance with the principle of realism when reasonably convenient. Thus, in a charger the 'slew' control might move in a line across the driver.

These principles cannot be rigidly applied, but they can be applied more frequently than they are. Their implementation should increase speed and efficiency.

Pattern of Controls

Studies of human characteristics have improved the planning of all kinds of repetitive tasks.

The most frequently used controls should be placed at the positions most convenient to the driver's hands, as laid down in the B.I.S.R.A. specification. This also applies to those controls requiring the most care in operation. It is not easy to define which controls these are, but it seems reasonable to include the main hoist, the main cross-travel motions, and the long-travel motion.

Great precision is not generally required in setting crane controls, since they are variable in steps, not continuously. The important requirement in a multi-motion crane is high speed of operation, and for this the sequence of hand motions should be the simplest and shortest possible. The necessary data can only be obtained by sustained recording of the motions of the operator's hands in representative cranes. As far as is known, no work has been done on this type of research, which has been most fruitful in much repetition work and is a subject worthy of further study in relation to crane cabs. The technique is well established.[4]

Whatever the pattern of controls, the spacing can be reduced by arranging for the controller handles to be on the side inboard to the driver. Thus, a radially arranged B.I.S.R.A.-type controller on the driver's right would have its handle on its left side as viewed by the driver. This brings the handles in a compact group, since the distance between the handles of the outer controllers is minimized. Left- and right-handed controllers are necessary, but this is a normal requirement presenting no difficulty.

Principle of Distribution and Foot Controls

The principle of distribution means the distribution of the work to the best advantage between both hands and feet. Considerable improvements are possible merely by co-ordinating the movements of the two hands without regard to the feet, and Chapanis, Garner, and Morgan state that by designing a layout so that both hands can be used to their fullest extent, 50–80% of the time for a particular sequence of operations can be saved.

The main principle from the point of view of crane-cab design is that of simultaneous motion, in which both the hands are used at once, and the work is arranged so that a fair share is taken by each hand.

Many operations concerned with moving materials in a steelworks, *e.g.*, loading scrap boxes and lifting them to the furnace stage, stacking coils of strip, etc., involve movements that are cyclic or closely repetitive. Further study would teach more about desirable control patterns in steelworks cranes or chargers and would increase speed of operation.

Some progress has been made in the design of foot controls in Great Britain, but in crane cabs these are confined to braking pedals or simple magnet controls. Large ungainly mechanical brake pedals are rapidly being displaced by small, comparatively lightly operated, hydraulic pedals that are much more amenable to integrated design (*see* B.I.S.R.A. specification, clause 165).

Foot magnet controls are simple 'two-way and off' switches, ironclad to withstand rough usage, but more complex magnet switches, with several steps for picking up different numbers of plates, are usually hand-operated. Foot controls are also used in the cabs of excavators and control pulpits (*see* Figs. 14*a* and *b*).

In the U.S.A., some progress has been made in foot control in crane cabs. Figure 15 is a reproduction from an advertisement[10] that appeared in 1945, showing an American crane cab in which, according to the caption, "Each of the operator's limbs has one definite control job—no double duty."

These examples show that it is recognized that the foot provides adequate control, and its further use in cranes should be studied.

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Distinguishability of Controls

Chapanis, Garner, and Morgan[4] deal with the subject of distinguishability of controls in some detail. They consider it important to do everything possible to make controls distinguishable, and suggest five ways of doing so:

(i) Make controls obviously different in location, even when the operator is not looking at them
(ii) Make controller handles different in size
(iii) Make handles different in shape
(iv) Make handles different in colour
(v) Label controller casings.

At present, steelworks controller coding is confined to labelling, with some attempt to use location of controller as an added indication.

The excellence of the principle of ensuring distinguishability of controls will not be held in doubt, but the industry as a whole is not yet ready to exploit it fully.

Installation of Controllers

Controllers with straight-line operation, such as the B.I.S.R.A. four-start type, should be installed on low angle-iron frames or box mountings bolted firmly to the cab floor, and the fastenings should be confined to the bases of the controllers.

The two controllers nearest to the fore and aft centre-line of the controls need to be installed near the front corners of the seat, but the controller bodies are comparatively low, and these should not impede access to it. Where there is insufficient access, a low step can be provided on one side of the seat, but, in modern installations of conventional controllers near seat corners, no step is considered necessary. An example is shown in Fig. 4 of Part I.

Conduits from the controller bases should be kept short by taking them straight down to the floor, where they should disappear into ducts flush with the floor. All other wiring should be carried in those ducts.

Orientation of the Cab Relative to the Crane

The orientation of the cab in relation to the working area over which the hook or working point of the crane travels is still receiving insufficient attention. Building a crane cab ' square ' with the sides or ends of the crane, although cheaper, should be abandoned in some cases. It is a good rule to arrange that the operator, when seated normally, is looking approximately at right-angles through the front of the cab at the hook or working point. In cranes with fixed cabs, a central position of the hook should be assumed, unless there is a definite bias from the centre for its most usual or most important working position. While ' skewing ' fixed cabs, it should be borne in mind that the operator must, in general, be able to look out of the side window on the hook side, so that this side of the cab should be parallel to the cross-travel rails. One modern steelworks has recently improved cranes by ' skewed ' designs, and an example is shown in Fig. 4c in Part I.

Another poor feature of cab design often found in ingot-handling or other moving-cab cranes is when the cab is buried in the middle of the massive structure comprising the crab; it seems as though the cab has been accommodated as an unwelcome necessity in the mechanical design. The result is that although the jaws or tongs are reasonably visible (when the driver is standing), he cannot see both ways in the direction of cross travel and both ways in the direction of long travel. In many cranes, he cannot see at all in at least one of these directions.

Crane cabs with none of these disadvantages can be designed at little extra cost, and it is time that the problem of orientation of the cab was regarded as one of design integral with the crane.

DESIGN OF CRANE CABS

Summary of Basic Criteria

The essentials for fixing the relative positions of the crane seat and controls in relation to the front of the cab and, where necessary, in relation to the side of the cab adjacent to the crane hook, may be summarized as follows:

(i) The controls and the crane cab should form an integrated design that should allow the operator to attain his maximum speed and efficiency
(ii) The design should accord with the B.I.S.R.A. specification for heavy-duty electric overhead travelling cranes
(iii) The seat should be designed on anthropometric data and should be similar to the anatomical seat designed for naval purposes
(iv) The average height of the control knobs above the floor should be about 30 in.
(v) The Barnes working areas should be adopted
(vi) If isolated controls are placed well above or below the main horizontal plane of working, the maximum reach distances defined by Lipschultz and Sandberg should not be exceeded
(vii) No item operated by hand should be mounted within a 16-in. wide space directly in front of the operator
(viii) The seat should have its centre symmetrically placed 2 in. in front of the straight line bounding the Barnes working areas. If the anatomical seat is used, this dimension applies to the centre of the seat pedestal
(ix) When no foot controls are provided, the line of the cab front at floor level immediately in front of the operator should be 24 in. in front of the centre of the seat
(x) When foot brakes are provided, the dimensions of the interior of the cab front should be not less than those given in Fig. 11, and foot pedals should be arranged as shown in this diagram
(xi) The size of opaque wall panels should be reduced to give the maximum visibility consistent with the duty of the crane
(xii) Where practicable, no front vertical member of the cab should have an apparent width of more than 2 in. when seen from the operator's normal position
(xiii) A minimum of 4 in. clearance should be left between the controller casings and the cab front
(xiv) Straight-line or near straight-line controls should be radial from the shoulder points rather than circumferential around these points
(xv) Realism in controls should be adopted where possible, especially on the main motions, but not at the expense of integration of design
(xvi) Where possible, realism should be enhanced by the use of joystick controls
(xvii) The control pattern should be such that movements of the hands between controls are reduced to a minimum, consistent with other requirements being met. The most frequently used controls should be most convenient to the operator's hands
(xviii) The control pattern should make full and, as far as possible, equal use of both hands

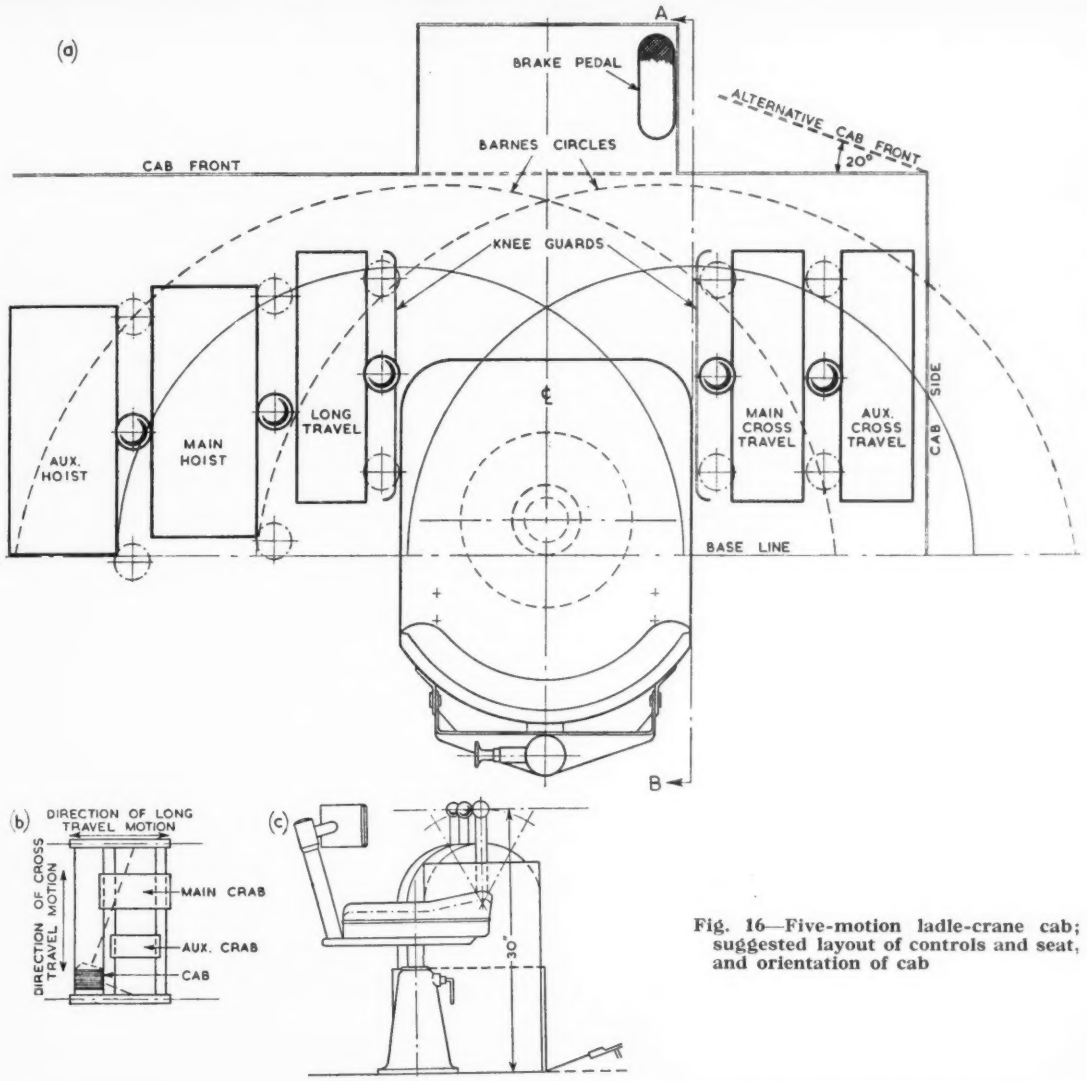

Fig. 16—Five-motion ladle-crane cab; suggested layout of controls and seat, and orientation of cab

(xix) Consideration should be given to the use of foot controls of the on–off type (*e.g.*, magnet controls and brakes), whenever possible. The pedals should be small and light, and should not impede the feet

(xx) The controls should be firmly bolted down to the framework fixed to the floor

(xxi) Wiring should be carried in short conduits disappearing directly into flush ducts.

Types of Multi-Motion Crane

Multi-motion cranes are cranes with five or more electrically controlled motions. Among the more orthodox types are:

Ingot-handling cranes	5 motions
Magnet beam cranes	5 motions
Large ladle cranes	5–6 motions
Ingot-stripping cranes	5–6 motions
Charging machines	5–7 motions
Box-charging cranes	5–8 motions
Box-lifting cranes	6 motions.

The word 'crane' is used here in its broadest sense to include the charging machine, which has the same function as the others of moving materials in three dimensions. There is little to distinguish an overhead charger from an overhead travelling crane.

In large ladle cranes, speed is less important than in the other types named, although an emergency on any crane may call for high-speed operation of the controls. It is therefore fully justifiable to apply scientific principles to the designs of cabs for these cranes as well as for the faster types. The argument also applies to some extent to production cranes of the simple three- or four-motion type.

These basic principles of crane-cab design have been applied to three of the above types of crane. The designs evolved should not be considered as standards, since design must be governed by the special features

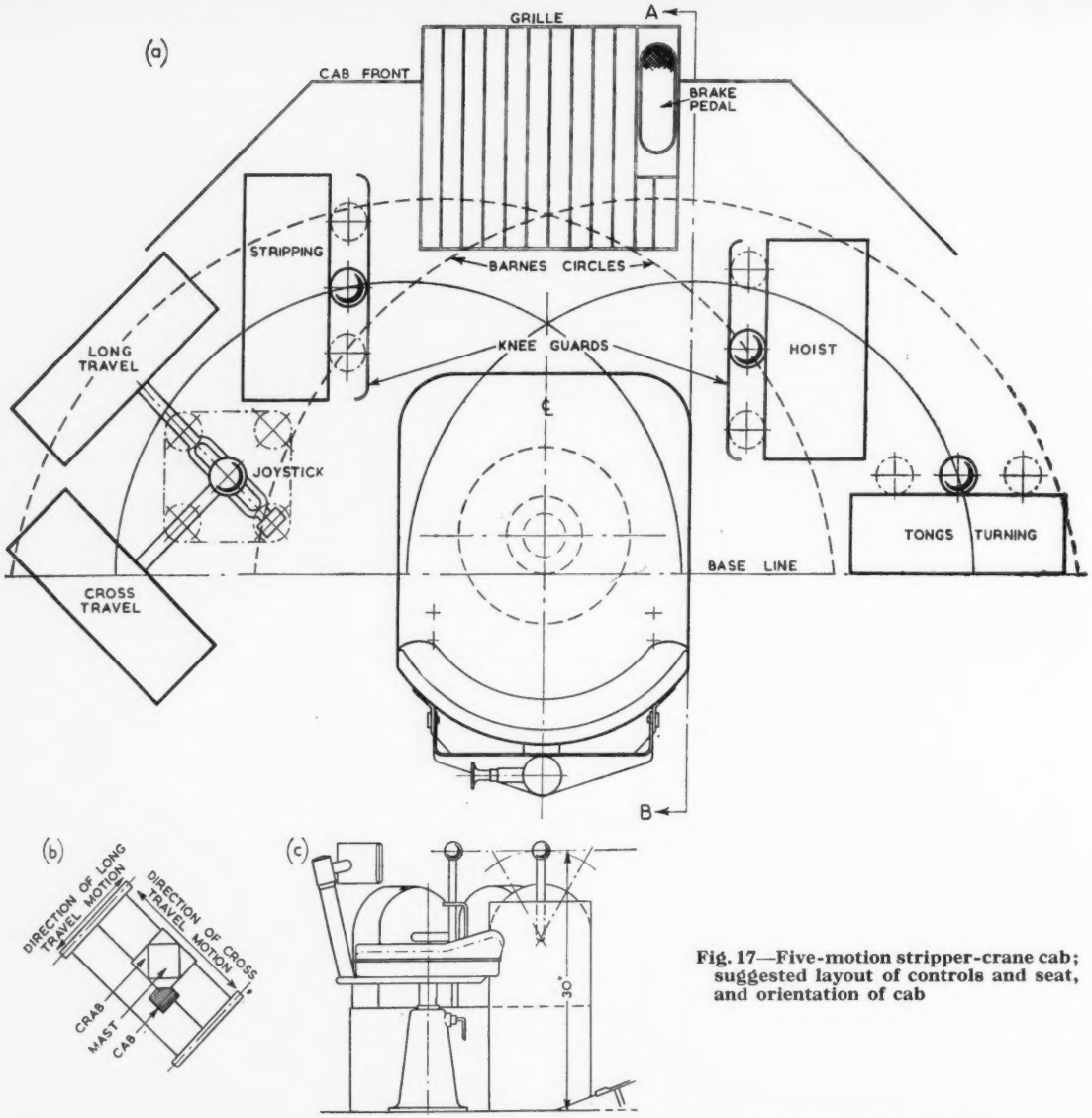

Fig. 17—Five-motion stripper-crane cab; suggested layout of controls and seat, and orientation of cab

of each crane; the idea is to show how the principles may be applied to any crane.

Basic Design of a Ladle-Crane Cab

The assumptions are as follows:

Five motions in a fixed cab, comprising main hoist, auxiliary hoist, main cross travel, auxiliary cross travel, and long travel. A hydraulic foot-brake pedal for the long-travel motion is operated by the driver's right foot. Driver looks across the full width of the shop, and both hooks are on his right. Controllers shown in Fig. 6 of Part I are used—two wide and three narrow.

The suggested design is shown in Figs. 16*a* and *c*. The controls are arranged in a row, and realism is achieved in all except long travel. All controls can be reached by the driver while seated, even if he puts his head out of the side window to see some special view, and the main controls are at the most favourable positions. All control handles lie within the normal Barnes working area, except the auxiliary hoist, which is within the maximum working area. All controllers are accessible for inspection and maintenance.

The foot pedal, in accordance with the recommendations in Fig. 11, is displaced slightly to the right so that the foot does not normally rest on it.

Access to the seat is across the left front corner; alternatively, the two controllers next to the knees may be arranged further forward, to clear the leg while stepping into the seat. Another alternative is to skew the front of the cab as shown, and thus allow the driver to walk round the front of the left bank of controllers. Figure 16*b* shows the orientation of the cab relative to the crane.

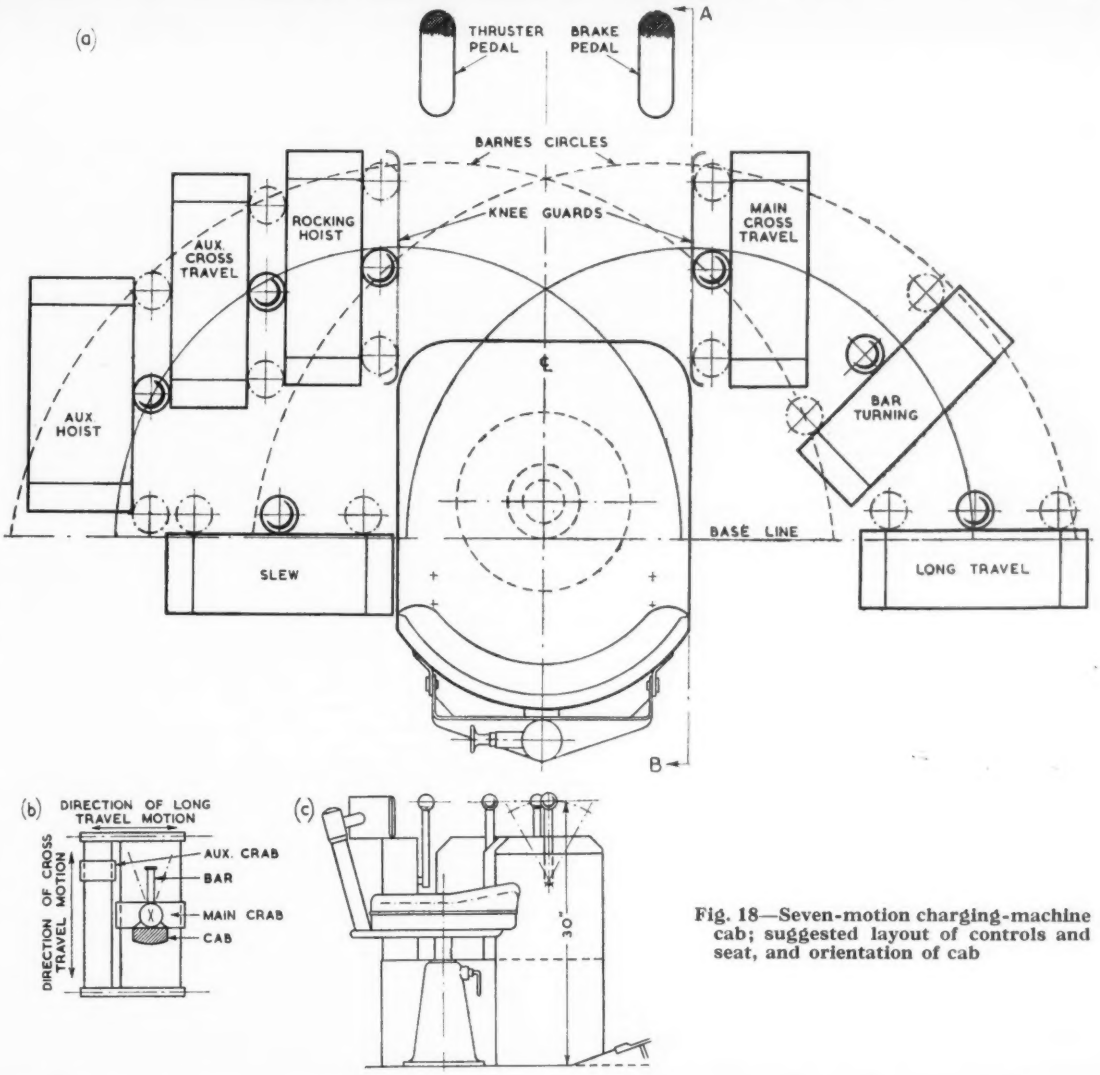

Fig. 18—Seven-motion charging-machine cab; suggested layout of controls and seat, and orientation of cab

Basic Design of a Stripper-Crane Cab

The assumptions are as follows:

Five motions in a moving cab, comprising long travel and cross travel combined in a joystick control, hoist, stripping, and tongs turning. A hydraulic foot pedal for the cross-travel motion brake is operated by the driver's right foot. The driver looks, through a floor panel or front glass panel extending to the floor, directly at the jaws. The controllers shown in Fig. 5 of Part I are used—one wide and four narrow.

The suggested design is shown in Figs. 17*a* and *c*. The joy-stick arrangement is on the driver's left, and it embodies realism in both directions, *i.e.*, movement of the joystick in a given direction will cause the crab and mast to move approximately in that direction. The comparatively small area traversed by the joystick knob during manipulation of the controls shows how suitable the new type of controller will be to this application.

All controls except the 'stripping' control embody realism in the fullest sense. All the handles fall within the Barnes maximum working area, and are in the normal area for a large part of their travel. All controllers are accessible for inspection and maintenance.

The distance between the left- and right-hand groups of controllers is widened out to 20 in. to allow the driver to look down between his knees. The sloping footboard of Fig. 11 is replaced by a grille, beneath which is a window of armoured plate glass that is carried forward to meet the window in the cab front. The grille is wide enough to take the driver's feet with a good space between, so that he can look almost vertically downward while manipulating the jaws. The foot pedal for the cross-travel brake, which complies with Fig. 11, is slightly to the right of the grille, so that the foot does not normally rest on it.

Access to the seat is from the right-hand side across the seat corner. Visibility up and down and across the

shop in both directions is provided by the special orientation of the cab shown in Fig. 17*b*, and the main mast members are arranged so as not to impede the operator's view.

Basic Design of an Overhead Charging-Machine Cab

The assumptions are as follows:

Seven motions in an overhead charger cab, comprising long travel, main cross travel, rocking hoist, bar turning, slewing, auxiliary hoist, and auxiliary cross travel. In addition, foot pedals are provided: the one on the right operates the cross-travel hydraulic brake and that on the left switches a thruster operating the box locking-bar. The driver is situated centrally to look directly along the bar. Controllers shown in Fig. 7 of Part I are used—one wide and six narrow.

The suggested design is shown in Figs. 18*a* and *c*. All seven controls incorporate realism in their movements. All the handles fall within the Barnes maximum working area, and are in the normal area for a large part of their travel. The main motions are most convenient to the driver's hands, and all controllers are accessible for inspection and maintenance.

The foot pedals are in accordance with Fig. 11, and are displaced slightly to the right and left respectively, so that the feet do not normally rest on them.

Access to the seat is from the right across the seat corner, and visibility is satisfactory in all directions.

CONCLUSIONS

(1) General design of crane cabs should be in accordance with the B.I.S.R.A. crane specification

(2) Controllers with straight-line action can be used with advantage, and the layout of controls should be in accordance with the 21 points listed on pp. 64–65.

(3) Marked improvements in crane cabs are possible by following these design criteria, which are based on scientific principles.

FURTHER DEVELOPMENTS

Much remains to be done both on the development of controllers and their application at control points, and it is hoped that this paper has indicated some of the fields in which progress is required. Possible developments are summarized below, so that some basis exists for the planning of future work.

Controllers

(i) Further reduction in size of controllers is possible and would be an important improvement

(ii) Curtailment of the number of notches necessary in a controller offers one of the most promising possibilities of improvement in cab layout and control

(iii) The correct amount of pressure needed to operate a controller should be determined, and joysticks, which are particularly applicable to the new controllers, should receive attention

(iv) The bounds of control possible with the feet should be determined, and foot-operated master controllers should be designed on this basis.

Control layouts and crane cabs

(v) Modern methods should be applied to determining the best layouts for a given number of controls

(vi) Data should be obtained about the importance of realism in relation to crane-cab design, and about the respective advantages of radial and circumferential control movements

(vii) The possibilities of using composite designs of crane cabs (*e.g.*, using four-start controllers for the main controls and the smaller single-start types for auxiliary controls) might prove a useful study.

General

(viii) These do not exhaust the possibilities in the design of crane cabs; experiments on size, shape, and colour coding of controller knobs could lead to improvements in distinguishability, and the effects of temperature and humidity, oxygen deficiency, vibration, noise, lighting, and colour are all important factors.

Acknowledgments

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Acknowledgment is due to John Wiley and Sons, Inc., New York, for permission to quote from "Applied Experimental Psychology" by Chapanis, Garner, and Morgan, and "Work Methods Manual" by Barnes.

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Revision of Crane Specification

The "Specification for Heavy Duty Electric Overhead Travelling Cranes for Use in Iron and Steel Works," published in May, 1950, has been revised in the light of operating experience. Amendment slips are available free from the Association at 11 Park Lane, London, W.1. The amendments relate chiefly to a re-assessment of the forces arising from acceleration and braking, and a closer definition of some permissible stresses; tolerances for standard crane couplings; provision of E.M. shunt brakes with rectifiers on A.C. cranes, and of cross-travel conductors on certain cranes for subsequent fitting of magnets; and the clarification of the main control-gear layout diagrams.

Rehabilitation of a Slab Mill Without Loss in Production Time

By A. Taylor, M.I.Mech.E.

SYNOPSIS

The paper describes the rehabilitation of a slab mill which was carried out over a period of six years, without interrupting production. The work consisted of electrification of the mill drive, installation of a new 50-ton overhead crane, conversion of a universal edge mill to a slab mill; and installation of much ancillary plant, including ingot chair, ingoing and working tables, manipulators, sheais, outgoing run-out, crop handling arrangement, and mobile transfer table. Details are given of the electrical equipment and the civil engineering work involved in preparing new foundations.

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DEVELOPMENT and modernization of the South Durham Steel and Iron Co., Ltd., West Hartlepool, commenced in 1937 and a modern light plate mill comprising a 2-high roughing stand and a 4-high finishing stand with continuous normalizing, slitting, and shearing, capable of producing 72-in. wide plates, $\frac{1}{8}$–$\frac{1}{2}$ in. thick, plain and checkered, went into production in 1939.

The outbreak of war prevented further development as all the Company's resources were directed to wartime requirements. At the end of the war the modernization process was continued, and this paper describes the rehabilitation of a slab mill which was carried out between 1946 and 1951 with a minimum of interference with normal production. The throughput of slabs was increased as the stages of rehabilitation progressed.

The original layout of the mill (1944) is shown in Fig. 1. The various stages of rehabilitation are summarized below and are indicated in Fig. 2, which shows the final layout.

Stage 1—Electrification installed. Foundation work and new motor-house provided, new 50-ton overhead crane. Actual changeover during normal weekend stoppage, February, 1946.

Stage 2—Installation of converted universal vertical edge mill to slab mill, together with ingot chair, ingoing table, and working table. Provision for electrically driven side-guard type manipulators on ingoing side. Breast roller drives and motor installed; complete new foundations for mill and tables and new equipment installed, August, 1950 (2 weeks' stoppage).

Stage 3—Ingoing side manipulators installed, resiting of mill drives control pulpit, May, 1951.

Stage 4*a*—Preparation for final stage. Installation of shears and outgoing run-out, measuring stopper gear, crop handling arrangement, etc., before the August, 1951, holidays.

Stage 4*b*—Final stage. Removal of all outgoing tables, old shears, and run-out. Installation of new outgoing tables and foundations from mill to shears. Completion of outgoing side manipulators and mobile transfer table for sheared slabs, August, 1951 (2 weeks' stoppage).

The scheme may appear to lack strict sequence of execution, but when a major plant replacement is being carried out over an extended period under operating conditions the whole conception of the original scheme may be altered, as each phase of development may demand adjustment in accordance with the prevailing circumstances. Consequently, programming and progress must be adaptable and flexible.

PRELIMINARY CONSIDERATIONS

Owing to the great advance in welding technique and fabrication it was evident that any post-war slab mill development should have regard for the demand for wide slabs as a sales product. The increasing demand for welded pipe manufacture required by the associate works, together with the expansion of welded fabrication and mild-steel tank manufacture for high-pressure vessels and the demand for wider plates for the shipbuilding industry, created a demand for the economic production of wider plates and direct slab manufacture. After considering all the relevant factors it was decided that the new mill should be capable of producing 50-in. wide slabs.

With an overall planned ingot-producing capacity for the works of 500,000 tons per annum the most economic ingot weights to be produced were 15 and 10 tons respectively to cover slab sizes for the adjacent heavy and light plate mills. It was anticipated that there would be no appreciable increase in the number of ingots to be handled with the higher level of ingot throughput and this, together with the great importance of high slab yield from an ingot, were the main points which assessed the requirements of the proposed slab mill.

The mill driving motor capacity depended on several considerations, it being the policy to concentrate the ingot production within the works and at the same time to provide for a substantial increase

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This paper was presented at a meeting of Junior Engineers, held at Ashorne Hill, Leamington Spa, from 19th to 21st May, 1952.

Mr. Taylor is a Director and Group Chief Engineer at the South Durham Steel and Iron Co., Ltd.

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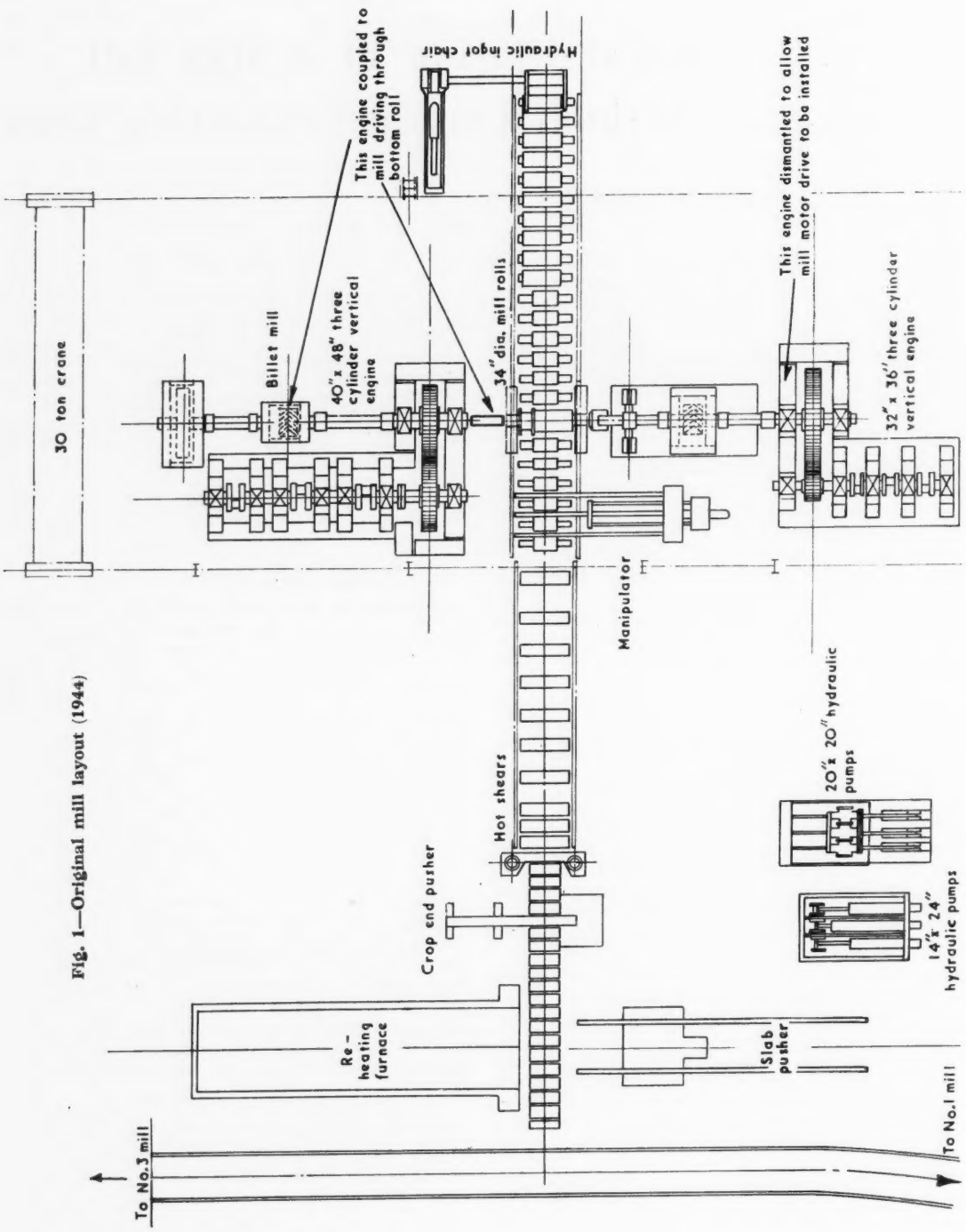
Hydraulic ingot chair
This engine coupled to mill driving through bottom roll
This engine dismantled to allow mill motor drive to be installed
30 ton crane
Billet mill
40" x 48" three cylinder vertical engine
34" dia. mill rolls
32" x 36" three cylinder vertical engine
Manipulator
20" x 20" hydraulic pumps
Hot shears
Crop end pusher
14" x 24" hydraulic pumps
Re-heating furnace
Slab pusher
To No.1 mill
To No.3 mill

Fig. 1—Original mill layout (1944)

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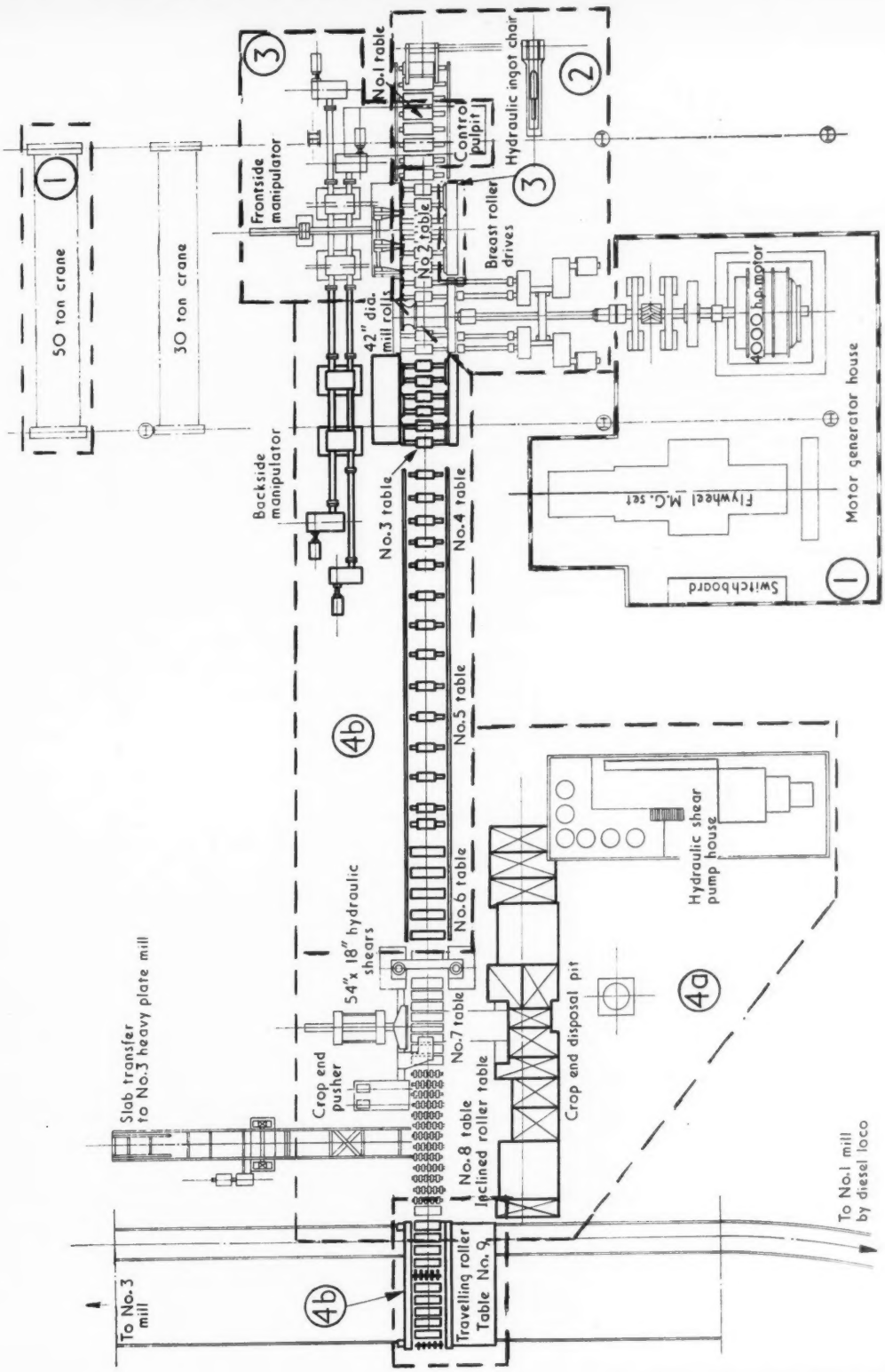

Fig. 2—Final layout of mill, showing each stage of the rehabilitation

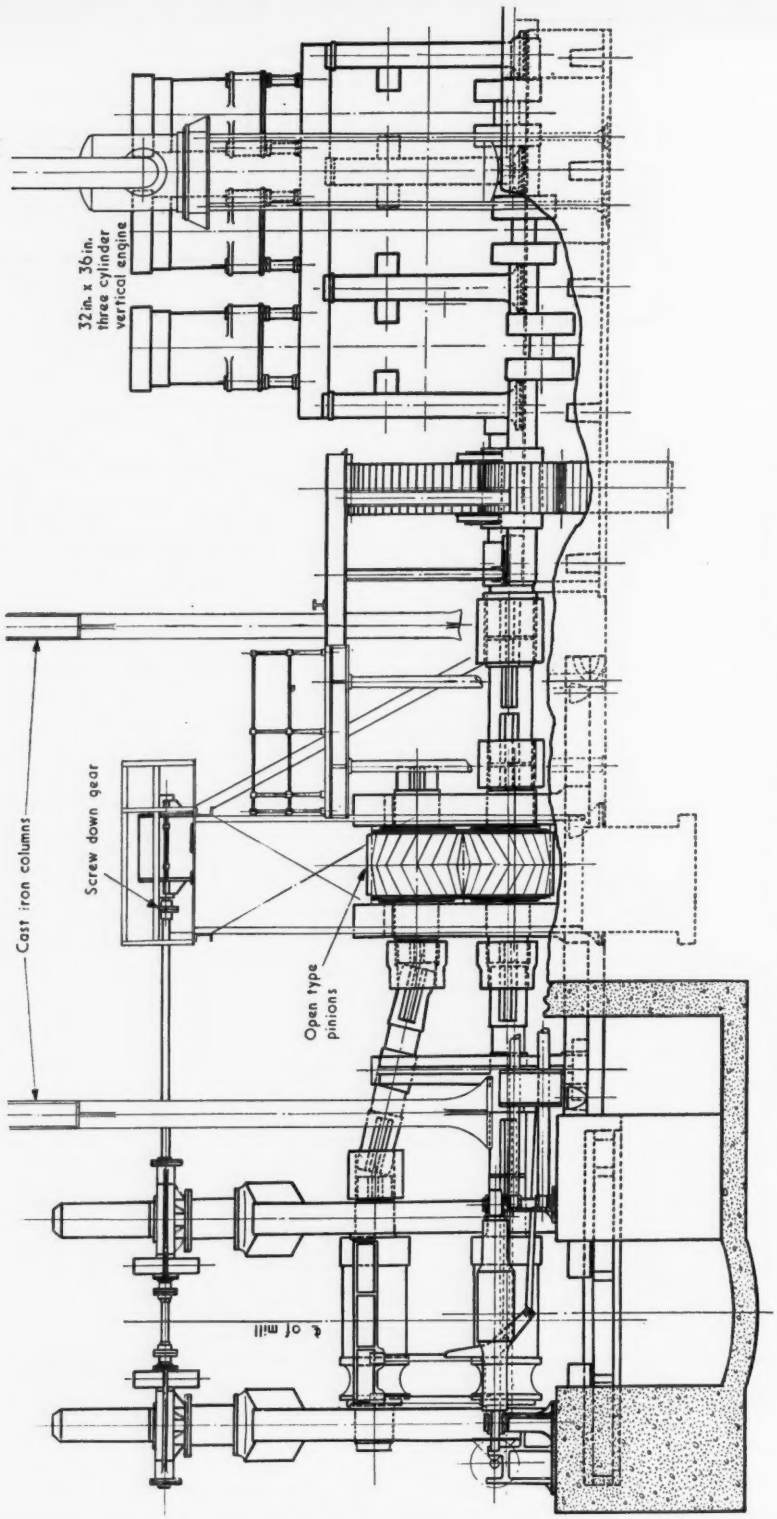

Fig. 3—Cross-section of the original steam-driven cogging mill

of the total output of plates, together with the possible demand for wide slabs direct from the slab mill. A considerable margin had to be allowed to leave the mill sufficient slabbing capacity for feeding the light and heavy plate mills with the wide range of sizes necessary to give the greatest possible advantage for hot slabs charged as required by the respective mills.

In regard to ingot heating, consideration had to be given to the flow of steel from the adjacent four steel furnaces, which would eventually be increased to five operating furnaces, together with the amount of weekend make of cold steel to be heated up. It was finally agreed that the electrical equipment should be capable of rolling an average of 100 tons/hr. and for the heavier slabs 130–150 tons/hr. on continuous rating.

The main features required of the slab mill were:

(*a*) A roll lift to edge a 50-in. wide slab with a high-speed screwdown for speedy adjustment of rolls for reasonably heavy drafting
(*b*) A quick-operating manipulator of the sideguard type to handle the wide slab
(*c*) A robust breast-roll drive
(*d*) Working tables of robust construction capable of standing up to heavy shock loads and of giving speedy roller-table delivery from ingot chair to mill and from mill to shears.

The slab shears had to be capable of cutting the full range of slabs to be rolled, and for this 54 × 18-in. shears were required, the minimum slab size being 32 × 3 in.

Wherever possible the mill was to have standard motor drives for all roller tables, etc., and the working and roller-table roller and bearing details were to be standardized whenever possible, all with oil-bath lubrication.

GENERAL DESCRIPTION OF REHABILITATION

Electrification of Slab Mill

The first stage of the general plan of modernization was to eliminate as far as possible the use of raw coal. The first essential was therefore the electrification of the slabbing and heavy plate mill drives, eliminating a medium plate mill which was also steam-driven.

The original mill was located in a very congested area and there was no alternative unrestricted site; hence great care had to be exercised in all development work since most of the existing plant was 40–50 years old and few details of the original construction were available. Every possible precaution had to be taken to check foundations, particularly where increased loadings were to be imposed.

The original slab mill (Fig. 3) had open-type driving pinions with cast-steel machine-moulded teeth, the top roll driving spindle being 12° to the horizontal with the top roll in the top position; this gave a very short life of wobbler spindles and boxes—an average of 25,000 tons per set of boxes and spindles. A separately mounted screwdown drive gave a maximum screw-down speed of 30 in./min.

On each side of the slabbing mill there was a steam engine; one was a vertical 3-cylinder engine, 32-in. dia., 36-in. stroke, 140 r.p.m., and 7000 h.p., used for driving the old slab mill; and the other, a vertical 3-cylinder engine, 40-in. dia., 48-in. stroke, 120 r.p.m., and 12,000 h.p., was located between the slab mill and the adjacent old heavy plate mill which had been used during the 'inter-war slump' period for producing billets in the plate mill roll housings.

It was therefore arranged to utilize the latter engine as a temporary means of driving the slab mill pinions through the bottom roll, so that the space occupied by the engine which had previously been driving the slab mill could be cleared (*see* Fig. 1). This, together with the re-siting of the hydraulic pumps, etc., enabled a site to be prepared for foundations of the new mill motor-generating sets and auxiliaries, and the mill pinions and for the foundations of cranes for erecting the electrical equipment, to be housed in a suitable building with pressure ventilation.

As the old type of mill driving pinions, which had operated when the mill was steam-driven, would be totally unsuitable to transmit the torque from the proposed mill motor, a new pinion housing of welded construction, weighing 44 tons, was manufactured at the Company's associated works.

The erection of the mill motor required special care, as headroom for crane lift was very restricted; special lifting beams enabled the mill armature to be safely landed on its bearings. Similar precautions were taken with the flywheel set.

The electrical equipment of this drive comprises a reversing D.C. motor with a nominal rating of 4000 h.p., 43–90 r.p.m., 840 V., the power being supplied from a flywheel motor-generator set. The motor-generator set consists of a 3000-h.p., 592–742-r.p.m., 11,000-V. induction motor with two 1615-kW. generators and a flywheel having a stored energy of 150,000 h.p.sec.

The working peak is 167 metre tons and the maximum cut-out torque is 200 metre tons. The mill motor and electrical equipment is capable of rolling a 50 × 8-in. slab from a 15-ton ingot in 41 passes and 7 edging passes in 270 sec. with 3 sec. between flat passes and 8 sec. and 5 sec. respectively on upending, and returning with a 10-sec. interval between ingots; this would correspond to a rolling rate of approximately 200 tons/hr.

As the average production rate required was about 100 tons/hr., ample margin existed over the normal production rate to avoid any risk of overheating due to overworking the electrical equipment.

Servo-motor control and Lockheed transmission were provided with the main controller situated in the motor room. The control lever can be moved from one extreme position to the other very rapidly with the minimum of effort and without the possibility of damaging the electrical equipment in any way. The rates of acceleration and deceleration are independently adjustable and enable the maximum output to be obtained from the mill consistent with the capabilities of the electrical equipment. Erratic movements of the driver's control lever are not transmitted to the main controller. The servo gear ensures a steady drive, giving smooth acceleration and deceleration to the mill.

The mill motor drives through a Wellman Bibby flexible coupling 12 ft. 0 in. dia., capable of a maximum torque of 250 metre tons, connecting the mill pinions which are located in the mill driving-motor house. The pinions, 39-in. face width and 42-in. pitch-line

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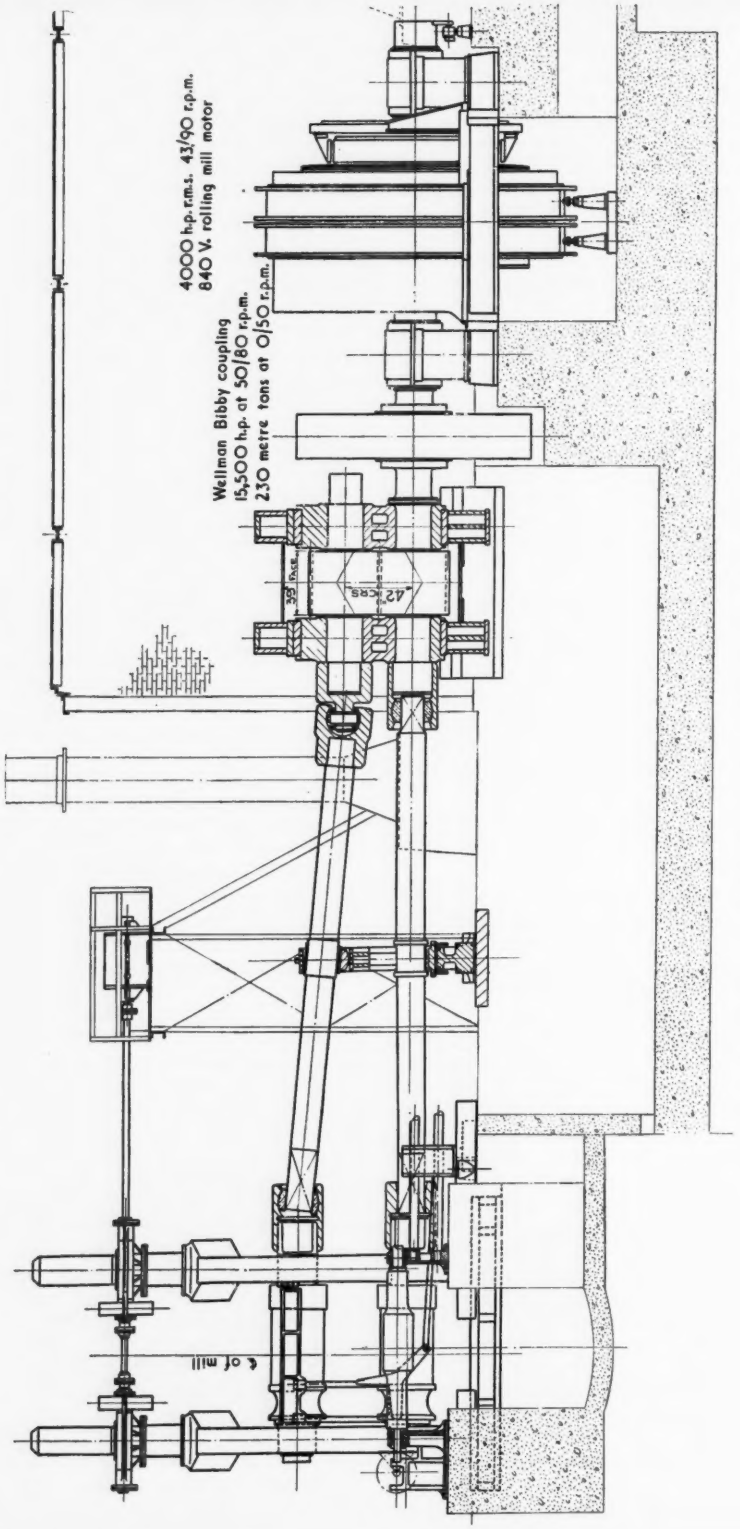

Fig. 4—Cross-section of the mill showing the electric drive (February, 1946)

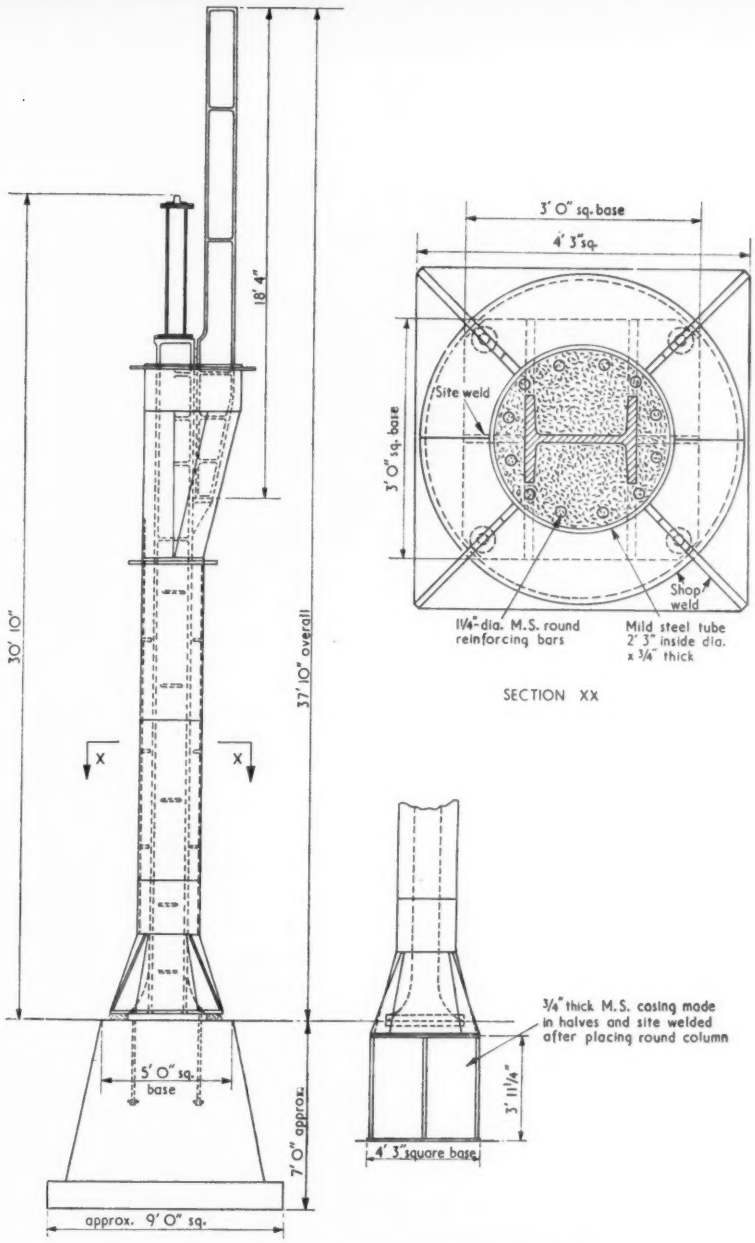

Fig. 5—Reinforcement of cast-iron building columns

diameter, are lubricated by a press system, both bearing and tooth face being spray-lubricated. The driving spindles are 22 ft. 3 in. long.

Figure 4 shows the electric drive coupled to the existing mill. The actual conversion from steam to electric drive was put in hand and completed in February, 1946, during a normal weekend stoppage, and merely involved changing the spindles and re-positioning the spindle balance to accommodate the longer driving spindles.

Reinforcement of Cast-Iron Columns

To deal with the weights of machinery parts eventually to be handled for the slab mill housings, etc., attention had to be given to stiffening-up the existing overhead crane gantry and crane spanning the slab mill; this was limited to 25-ton lifting capacity and lifts of 60 tons would be required.

The gantry columns were of cast-iron **H**-sections and also formed roof supports, the various buildings all converging to this transverse gantry and building.

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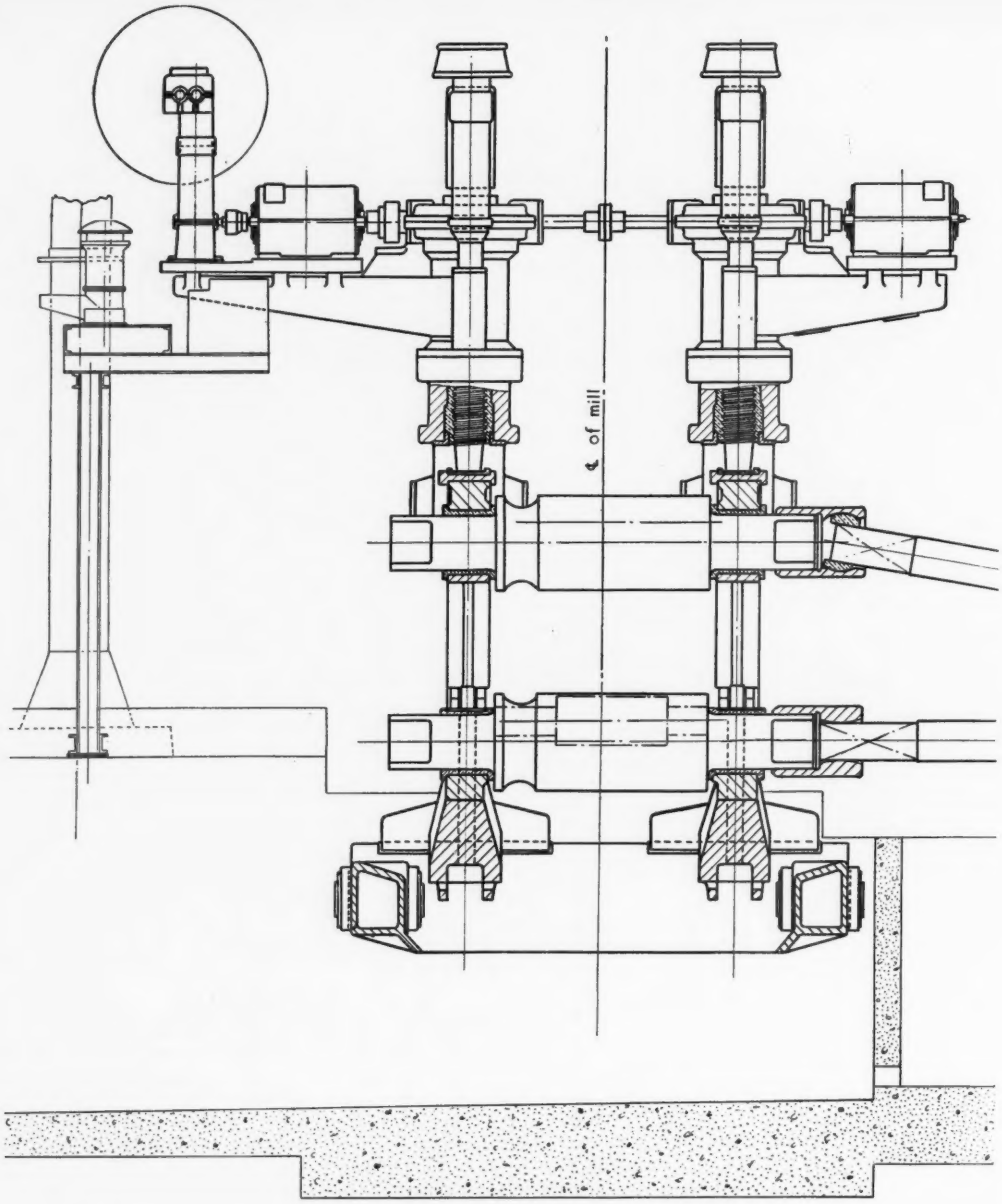

Fig. 6—Cross-section through rehabilitated slab mill

It was not possible to replace the cast-iron supporting columns without major interference to operations, nor was it possible to resite the gantry columns, owing to the congestion and clearances required to span the mill and equipment.

It was finally decided to encase the cast-iron columns in heavy steel tubing built *in situ* and welded in sections. The space between the existing cast-iron columns and the new steel circular columns was filled in with concrete containing specially selected granite chippings as aggregate and reinforced as far as practicable (Fig. 5). Also, the foundations were extended and capped to increase the area that was to accommodate the increased loading. Each column was treated as a separate problem.

When this work, which was carried out mainly at weekends, was completed, new gantry girders were mounted on the reinforced columns, and an additional 50-ton electric crane was put into operation on the gantry. The existing 25-ton crane was completely

overhauled. This enabled two cranes to operate on the gantry, thereby much improving the service to the slab and heavy plate mills.

To gain a further productive advantage over the interim period of development the spare cogging housings were altered to increase the lift of the top roll by 3 in. to obtain a corresponding wider slab. They were also fitted with top roll balance cylinders mounted on the housings in place of the original roll balance equipment, which was under the original housings and was always a source of trouble owing to its inaccessibility. The remodelled housings were installed on the existing bedplates and foundations during the next holiday stop period.

Meanwhile, the throughput rate increased from 4000 to 7000 tons of hot slabs per week; this had a very great influence on the output of the light and heavy plate mills.

Electrification and Rebuilding of Heavy Plate Mill

During this period, consideration was being given to the replacement of the slab mill with a completely new mill from the ingot chair to the shearing run-out. Circumstances, however, demanded urgent attention to be directed to the adjacent heavy plate mill, which was also to be electrified. This eventually resulted in a complete rehabilitation and re-arrangement of this plate mill from slab housing pits to final plate inspection, using existing equipment wherever possible to the best advantage. This occupied concentrated effort of the engineering resources for 7–8 months. The plate mill is illustrated in Fig. 8.

The plate production was then raised from 1700 to 3500 tons/week and proportionally increased the demand for slabs from the slab mill. The rebuilt plate mill was capable of producing plates 118 in. wide, compared with 102 in. wide. The soft stands were first mounted with 12-ft. barrels and operated for some time with the hard stands at 10 ft. 6 in. barrels, but owing to the relatively small demand for wider plates the soft stand was made the same as the hard stand, namely 10 ft. 6 in.; however, it can be changed at short notice. As a result of this development a medium plate mill, which had been very costly to operate, was eliminated.

Simultaneously, at the associated works of the Company, work was in progress to rebuild a 40-in. blooming mill, which was operating with a broken main roll housing, and at the same time to electrify the drive. When this was completed there was sufficient ingot rolling capacity at these works to render redundant a complete tandem 34-in. universal edging mill, which was installed new in 1937 and had been operating as a blooming mill intermittently. Attention was then directed to examine what equipment from this mill could be used for the proposed slab mill. The housings were of robust design, having a column cross-section of 890 sq. in., the barrel length being 8 ft.

The cast-steel housings and bedplates weighed 60 tons and 40 tons respectivly. The housings were connected to the bedplates with very substantial 'shrunk-on' rings with hinged plate doors for chock adjustment and fitted with a well-designed screwdown mechanism. It was decided that the universal roll stand could, with minor alterations (when stripped of the vertical edging roll equipment) be made into a very useful slab mill to give sufficient lift to edge a 50-in. wide slab. Figure 11 shows the universal mill housing assembled before installation as a slab mill.

It was then possible to determine the general outline and speed required of the roll screwdown, which was 200 in./min. This equipment, together with the various roller tables, became the nucleus for the eventual slab mill replacement in which 700 tons of machinery were used. The rehabilitated slab mill is shown in Fig. 6.

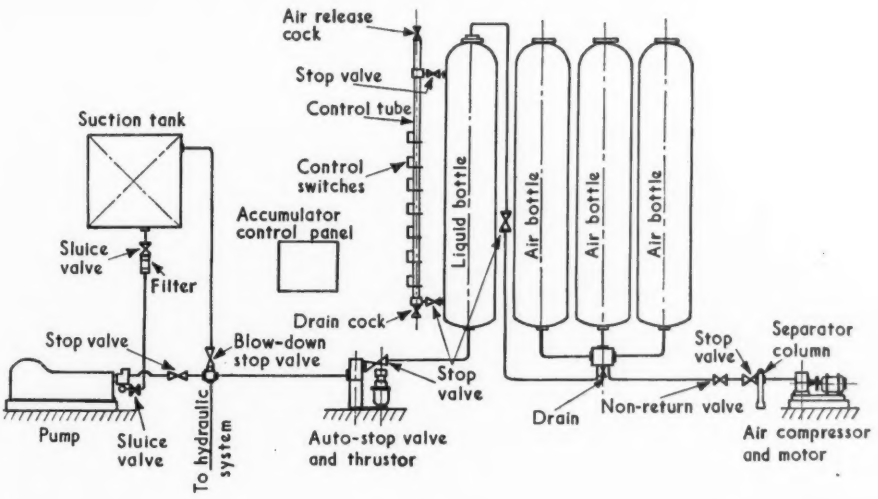

Fig. 7—Diagrammatic arrangement of air-loaded hydraulic accumulator with patent magnetic control

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Shears and Auxiliaries

Steps were then taken to complete the requirements from ingot chair to shears run-out and slab disposal. The shear capacity was determined and orders were placed for 54 × 18-in. air-hydraulic shears and auxiliaries. The power for the shears is supplied from a 275-h.p., 3-throw pump at 1·5 tons/sq. in., fitted with hydraulic mechanism delivering to a 300-gal. capacity air-hydraulic accumulator comprising one water bottle and five air bottles (Figs. 7 and 9). The shears are fitted with centring gear for centrally locating the uncut slab, together with crop-pushing equipment and an electrically operated measuring stop giving a maximum and minimum dimension of slab. The shears have cut a range of slabs varying from 3 in. thick to 18 in. thick and are of the down-and-up-cutting type, of 2500 tons capacity, and are capable of cutting the products of an ingot in six consecutive cuts at a rate of 3 cuts/min. up to 10 in. thick and 2 cuts/min. over 10 in.

The next stage was to install electrically operated sideguard-type manipulators with hydraulic tilting on the ingoing side to replace obsolete manipulators on the outgoing side of the mill. These manipulators (Fig. 10) were largely manufactured within the Company's resources, welded fabrication being extensively used. The electrical equipment and special gear boxes and heavy forgings were purchased from outside sources.

The final major stage included the installation of the new 54 × 18-in. slab shears (Fig. 12) and auxiliaries and all outgoing tables (from the mill and to new shears) with the necessary equipment. This stage required the removal of 450 cu. yd. of concrete and the laying of 480 cu. yd.

The shears had to be located so that they could be installed complete with stopper gear and run-out table prior to the commencement of replacement of all tables and foundations between the slab mill and shears; this could be done only during the annual holiday period. The site was available for this phase of the development when the medium plate mill had been eliminated by reason of the considerably increased output from the rehabilitated heavy plate mill.

The roller table is lubricated by a type DC.4 Farval fully automatic time-clock-controlled system operating on the loop principle and is a heavy-duty self-contained unit situated at a convenient point. It serves a total of 143 bearings at regular intervals controlled by an adjustable electric time-clock, which starts the 1-h.p. pump motor; pumping continues until sufficient pressure has been developed to operate all measuring valves. Once this pressure has been reached, a four-way hydraulic reversing and control valve operates and automatically stops the pump motor, which remains idle until it is restarted by the time-clock. At the same time, the flow reversing valve automatically relieves pressure in that line and resets for pumping on the second line. When the time interval has expired and the electric time-clock starts up the system again, the flow of lubricant travels through the other supply line. The large hopper-type reservoir has a capacity of 75 lb. of grease and is equipped with a heavy close-fitting follower plate to keep the pump primed at all times. This is a very satisfactory unit from all points of view.

As often happens when replacing old plant, the old shears, which were approximately 50 years old, had been causing considerable anxiety but it was hoped that they would continue to operate until the new shears were in commission. However, the main cross-head casting and cylinder block fractured and immediate steps had to be taken to maintain production while the extensive repairs were carried out, the shears being out of commission for just over a fortnight.

Fortunately, some experiments had been carried out in flame-cutting blooms and slabs, and an emergency arrangement for cutting slabs by special cutters enabled production on a reduced scale to be maintained. Slabs were received direct from the cogging mill, and in the case of large slabs for the heavy plate mill one crop-end was removed and one cut was made across the centre of the slab, thus leaving one slab ready for charging into the heavy plate mill furnace and one slab which required cropping. This crop was removed on the electrically operated hot-cropping machine with a Glasgow-type cutter, and the slab was transferred to the heavy plate mill reheating furnaces. Several small cutters were in operation to feed the light plate mill. During this period, 7267 tons of ingots were cut to slab thickness as required by the light and heavy plate mills—the actual plate production maintained being 71%.

There is undoubtedly tremendous scope for development of the oxy-acetylene cutting of slabs; this method could result in a radical change in the present conception of the cutting of hot steel by high-powered and costly slabbing and bloom shears and would provide more flexible working.

The new shears and ancillary plant had been generally assembled, leaving only smaller details such as piping and lubrication and the various access platforms to be completed before the mill stoppage for the annual holidays.

Preparation for Final Assembly

While the preceding work was being carried out all the preparatory work in connection with the major scheme was completed and every possible item which could be done to save any loss of time during the stop period was put in hand. Concrete was cut away to give quick access for the oxy-acetylene cutting of foundation bolts or separation of machinery to enable quick removal from site. The oxygen was supplied from pipelines arranged over the whole mill site with frequent tapping points to give operators maximum accessibility. Extensive drilling of foundations had been completed over previous weekends and the holes were plugged in readiness for charging with explosives so that blasting operations could be completed in a minimum of time when the site was available. Adequate protection against damage to electrical and other plant was carefully planned and all lifting appliances were specially overhauled to avoid any loss in handling time. Specific staff were detailed to give immediate attention to any mechanical or electrical failure.

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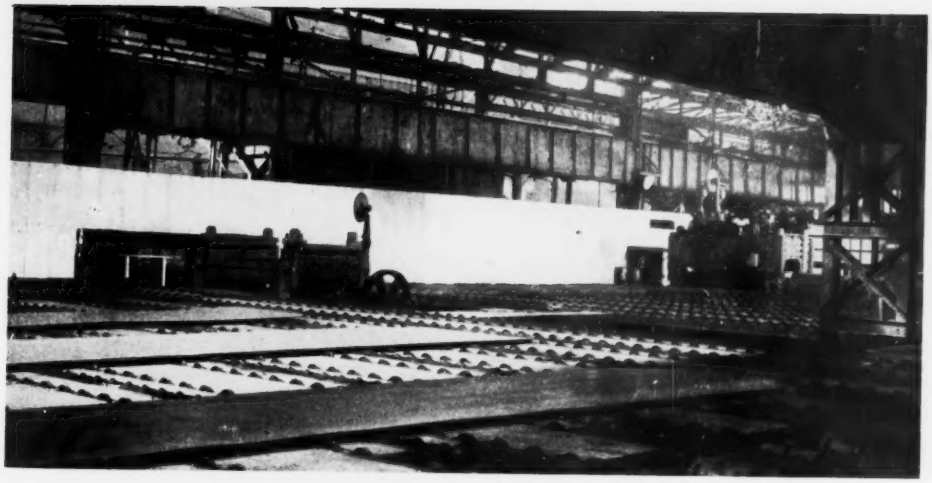

Fig. 8—General view of plate mill

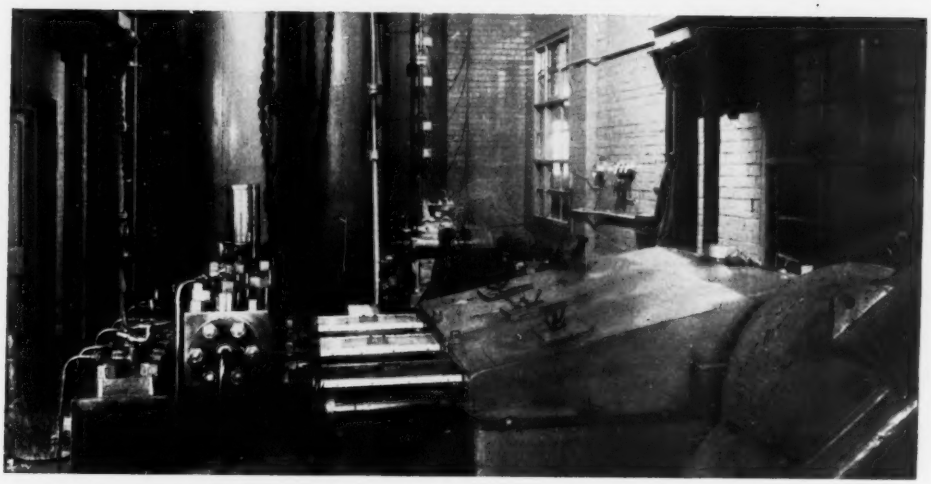

Fig. 9—275-h.p., 3-throw pump for operating shears. In the background are the air compressor and magnetic switches on the water bottle which control the safe working of the shears

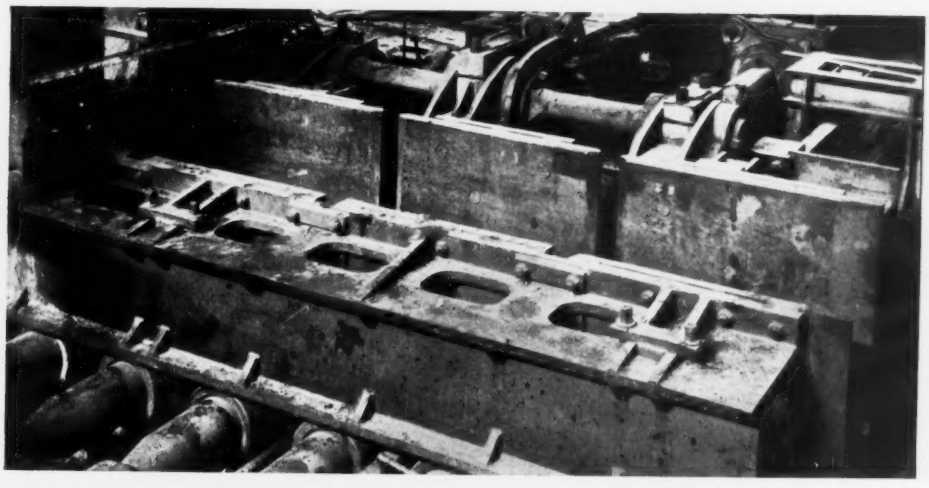

Fig. 10—General view of electrically operated sideguard type manipulators

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Fig. 11—Universal mill housing assembled after modification before installation as a slab mill

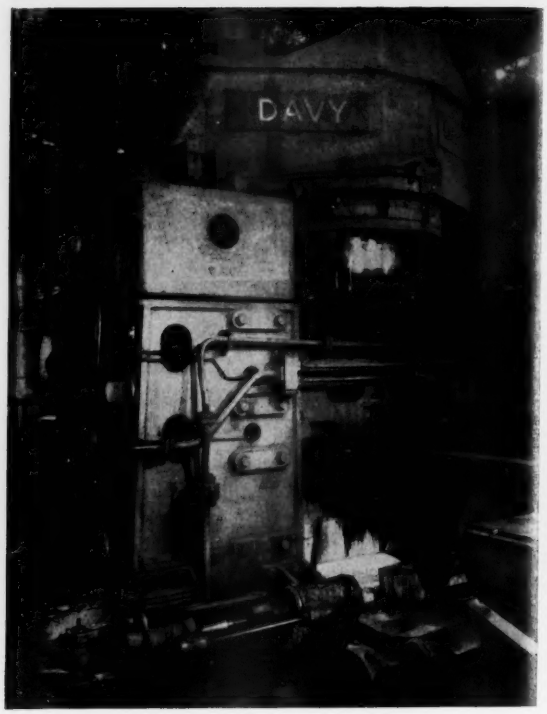
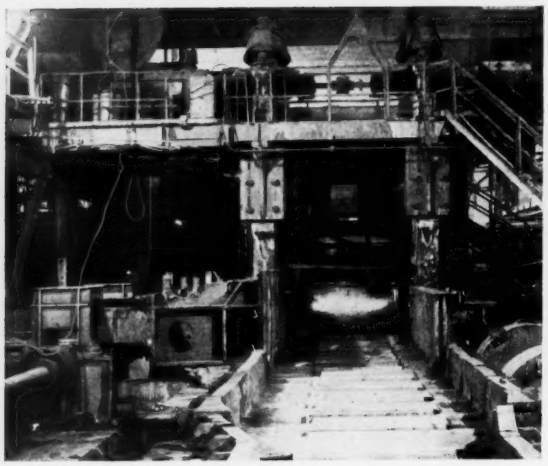
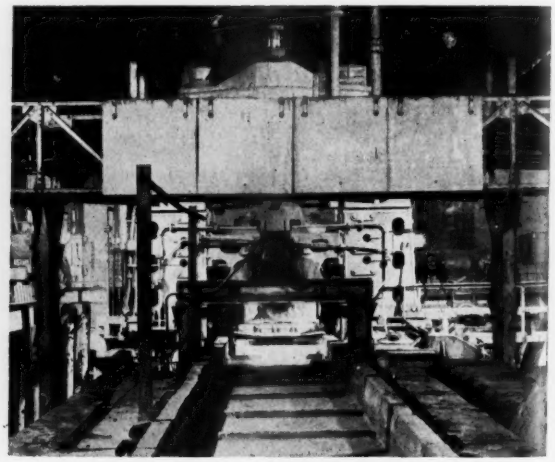


Fig. 12—General view of 54 × 18-in. slab shears



(*a*) Backside roller table



(*b*) Table to shears

Fig. 13—Completed mill

The several template boxes and much of the shuttering were reassembled at a convenient place near the site ready for speedy assembly, with locating marks and levels all conveniently placed for quick checking for final positioning. The sequence of this stage of replacement was to concentrate on the removal of foundations for the outgoing working table, together with the foundations for the ingoing table to the new shears, so as to allow the longest period period for the final assembly work that would occur on the outgoing table, which had to line up with the ingoing side manipulator drive; this was a very exacting site assembly.

Simultaneously, the foundations for the ingoing side shear roller table were pressed forward with all speed and the shear ingoing table and crop-end pusher were landed on new foundations as a unit. When this work was completed it permitted the erection of the cable bridge from the switch house to the various points required, which had already several cables all mounted on the bridge, each cable being identified for quick coupling up to the required unit to be powered.

With these two extreme tables in position concentration was directed to the completion of the centre-portion foundation work, which had been progressing, but without undue use of crane time that had to be expressly given to the assembly of the working table and the shears ingoing table. The assembly of roller tables over this section then progressed with the utmost speed as each section of the general programme was going according to plan. The settings of all tables were on predetermined packings all set in relation to the common datum.

A sequence of grouting-up of all bedplates followed as soon as the final location of bedplates was determined. The whole of the foundations were removed and new foundations were completed, with the final assembly of all plant, in 12 days, leaving reasonable time for mechanical and electrical details and for trial runs before the new plant went into production after the annual holiday period.

Figure 13 shows two views of the completed mill.

Completion of Rehabilitation

The final stage was the fitting into position of the outgoing manipulator sideguards provided for tippler gear if required.

To facilitate the removal of slabs a mobile table was also installed to enable the heavy plate mill adjacent to the slab mill run-out to be fed with greater speed with hot-cut slabs, giving more freedom of operation at the shears to cut thin slabs for the light plate mill. There are therefore three methods of clearing the cut slabs from shears to avoid any congestion under normal operating conditions.

ELECTRICAL DETAILS

All the electrical energy is obtained from the North Eastern Electricity Board, incoming at 20,000 V. and transformed to 11,000 V. when it is fed to the induction motor driving the motor-generator set and the mercury arc rectifier units from which the mill auxiliaries are all supplied at 230 V., D.C.

The changeover from the old mill to the new installation involved a completely new system of D.C. power distribution. This was located over the hydraulic pump house, the incoming feeders to the distribution board in the contactor house being 61/0·103 cables in parallel.

In August, 1950, during the annual holiday of a fortnight coinciding with the installation of the new mill housings, the front and backside roller gear drive, together with the chair roller gear drive, were taken out and replaced; the front with an 80-h.p. mill-type motor and a 40–80-h.p. motor for driving the front breast rolls, and the back with a similar machine to the latter installed on the back breast rolls.

Before the arrival of the Ward-Leonard set for the screwdown, the drive installed consisted of two 80-h.p. series motors connected in series and operated by an Allen West contactor panel housed in the operator's cabin.

Preparation for the second part of the programme scheduled for August, 1951, necessitated the erection of a new mill-operator's pulpit on the incoming side of the mill and the installation of a new set of control panels to enable the changeover to the new pulpit to be effected during a single weekend with no delay to the mill. Preparation was also made during this period for a complete renewal of the D.C. power distribution affecting this portion of the works. An 8-panel distribution board was erected and housed on the upper floor of the shears hydraulic pump house, to supply new feeders consisting of three 61/0·103 cables in parallel, which were run from the main works distribution board. The contactor panels for the shears and mill auxiliaries were also housed in this building, the requisite resistances being positioned on the roof above. The whole layout was compact and of easy access. The outgoing motor feeds were taken over a specially prepared cable bridge across the mill run-out track and *via* cable ducts to the requisite units.

The hydraulic pump providing power to the shears is driven by a 275-h.p. slip-ring motor with an oil-immersed stator switch and an oil-immersed rotor resistance. The hydraulic accumulator is of the air-loaded type with magnetic control, and initial air pressure in the air-hydraulic accumulators is obtained from a compressor unit driven by a 24-h.p. motor with a star-delta starter. The shears control is actuated by limit switches on the main block movement of the control handle. The above energizes a Londex relay, which in turn energizes three A.C. thruster motors on the control valves.

The liquid level in the air/water bottle of the accumulator is controlled by magnetically operated switches mounted on the side of the control bottle and operated by a magnet situated in a float, which rises or falls with the water level of the tube. The switches are connected with another Londex relay panel, which in turn energizes the thrusters operating the main stop valve and by-pass valve; by this means the pump is put ' on ' or ' off ' load. These switches also actuate lights, which set forth the actual water level in the bottle and also trip the main switch controlling the pump if too high a load is reached, or drop the stop valve in the event of the level falling too low.

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The old system of cabling was completely eliminated. Very considerable and complicated work was involved in the changeover without at any time causing interference with mill production.

CIVIL ENGINEERING WORK

The civil engineering work in connection with renewals of foundations required very careful planning. In the actual changeover stages when the roll housings and approach tables were undertaken (Stage 2) every possible cubic foot of concrete was cut away while the mill was working. During these preliminary operations holes were drilled in every point of vantage in the foundations to be removed, and at the appropriate time when all mechanical gear had been removed a sequence of pre-arranged blasting was carried out. Hence, foundation removal was largely a matter of crane handling capacity; this had also been programmed to obtain the maximum rate of clearing the site.

Meanwhile, all templates, boxes, bolts, etc., had been carefully assembled and each item marked up for quick re-assembly. Every possible step was taken to ensure that when the site was cleared the whole of the shuttering, bolts, etc., could be assembled in 2–3 hr. and concreting could be commenced from the time the site was cleared. Quick-setting Fondu cement was used very satisfactorily for most of the concrete work.

More than 650 tons of concrete were ' run-in ' within 20 hr. from the time when the templates were in position. This involved the careful siting of concrete mixers and the rapid feeding of each mixing station with materials, using overhead cranes to convey 'skips' containing up to 10 tons of concrete to the desired position. Loading on to foundations by the required machinery was put in hand in a matter of hours after the final set was observed in the cement.

Very careful co-ordination with the transport department was necessary as the removal of material to and from the site determined the rate of progress.

CONCLUSION

Reviewing the whole scheme of replacement from a time-schedule basis it would appear that a period of six years is excessive. However, a considerable amount of time was taken up in the manufacture of plant and, apart from the first stage, the changeover really occupied two consecutive annual holiday periods, each amounting to 13 working days, covering stage to stage. The remaining work was completed during weekend stoppages. With a clean and unrestricted site the project could have been completed in 2–3 months on an original schedule of erection.

There has been no attempt to install anything which could be said to be an innovation. The new plant is designed on sound and practical lines to give reliable service capable of meeting the demands and with capacity to spare for a comfortable margin of throughput.

The main rolls are not water-cooled on the barrels and give a long life (average 500,000 tons). To meet this condition the roll-neck bearings are of phosphor-bronze and are water-cooled although the bearing life and cost are lower than would be the case with white-metal bearings. The overall cost favours operation with dry rolls at high temperatures and some sacrifice to bearing life in terms of throughput per bearing.

Since completion of the rehabilitation scheme the general steel shortage has prevented any long-period observations of capacity in relation to the estimated rating, either electrically or mechanically, but actual rolling times of individual ingots rolled to slab size and shearing and disposal times have indicated that the mill is capable of a throughput rate well in excess of 100 tons/hr.

In a normal working period of 17 shifts per week, with an adequate supply of steel, the mill would slab 12,000–13,000 tons of ingots per week.

At the time of writing, the mill has, since 1946, rolled approximately 2 million tons at an average of 7500 tons/week, producing slabs 32–50 in. wide and 3–18 in. thick.

The original bottom spindle was changed owing to a fracture in the cast-steel driving box on the bottom pinion end. The wear on the universal coupling bearing brasses has been negligible. The driving pinions show no appreciable wear, due no doubt to the excellent electrical control and flexibility in the main driving Bibby coupling in taking care of shock peak which is intense when slabbing at a high rate.

The mill is controlled by one mill motor driver who is the ' cogger ' and operates the screwdown gear; a second operator controls the manipulators and roller table. The hydraulic shears are operated by a shear driver who executes the shear cut itself, the stopper, the ingoing and outgoing roller tables, the two centring devices and the crop-end pusher; a second operator controls the incline roller gear, scrap crop-end ' push off,' and the slab transfer, and also has access to the outgoing roller table if the other operator is engaged.

The mill has operated very satisfactorily and combined stoppages due to mechanical or electrical faults have been less than 1% of the operating time.

Acknowledgment

The author acknowledges with thanks the permission given by the South Durham Steel and Iron Co., Ltd., to describe the slab mill rehabilitation.

N E W S

ANNOUNCEMENTS AND NEWS OF SCIENCE AND INDUSTRY

THE IRON AND STEEL INSTITUTE

Changes on Council

The following have accepted invitations to serve as Honorary Members of Council during their periods of office:

Mr. F. KENNEDY, President of the Cleveland Institution of Engineers

Mr. R. S. BROWN, President of the Liverpool Metallurgical Society

Mr. T. G. GREY-DAVIES, Chairman of the Newport and District Metallurgical Society

Mr. H. N. BOWEN, President of the Swansea and District Metallurgical Society.

In addition, Mr. R. S. BROWN and Dr. L. B. PFEIL, F.R.S., have succeeded Mr. W. E. Bardgett and Mr. W. W. Stevenson as representatives of the Institution of Metallurgists.

President-Elect

At the Autumn General Meeting of the Institute, held on 25th–26th November, 1952, Mr. James Mitchell, C.B.E., Honorary Treasurer, was nominated to be President for the year 1953–54.

Special Meeting on Boron in Steel

At the suggestion of the Ministry of Supply, acting in conjunction with the Organization for European Economic Co-operation, the Institute is arranging to hold a special meeting on **Wednesday, 18th February,** to discuss boron as an alloying element in steel.

The meeting, which will be held at 4 Grosvenor Gardens, London, S.W.1, will be devoted primarily to the presentation and discussion of two papers: one on "Boron Steel Making," by H. F. Tisdale of the Molybdenum Corporation of America; and the other on "Use of Boron Steels," by H. B. Knowland of the International Harvester Company.

Further details of the meeting will be given in the February issue of the *Journal*, and a notice will be circulated early in the year.

Format of the Journal

At the request of the Council of the British Iron and Steel Research Association, papers submitted by the Association will no longer be segregated in a special section of the *Journal*.

All B.I.S.R.A. papers will in future be printed in the section or sections containing papers coming from other sources. The usual footnotes showing the origin and reference number of papers will be continued.

Special Report on Spectrographic Analysis

The latest addition to the series of Special Reports published by the Institute is a report on "*Spectrographic Analysis of Low-Alloy Steels*," prepared by the Spectrographic Analysis Sub-Committee of the British Iron and Steel Research Association.

The report surveys the spectrographic techniques employed in this country for the analysis of iron and steel, and a recommended method (based on the most successful of the alternative procedures examined) for the spectrographic analysis of low-alloy steels has been drawn up and given extensive trials on a series of chemically analysed standards, with very satisfactory results. The text has been divided into sections corresponding broadly to the sequence of analytical operations required. The applicability of alternative procedures or accessories has been described in several instances, and theoretical considerations and detailed operating instructions have been included where necessary.

The Report, No. 47 in the Series, is fully illustrated with diagrams and photographs, and is bound in cloth with stiff board covers. It can be obtained from the Offices of the Institute at 15 per copy, post free (7*s*. 6*d*. o Members).

Acta Metallurgica

A new international journal of the science of metals "*Acta Metallurgica*" makes its first appearance in January, 1953. This new journal, sponsored by the American Society for Metals and supported by many international metallurgical societies, will at first be published every two months.

The journal is intended to provide a medium for the publication of papers describing theoretical and experimental investigations that contribute to the understanding of the properties and behaviour of metals, in terms of fundamental particles, forces, and energies. It will include original papers, letters to the editor, book reviews, and occasional review articles. Papers are to be published in any language, with summaries in French, German, and English.

The Council of The Iron and Steel Institute has decided that the Institute should be a 'co-operating' society and as such it will be entitled, as one of a group of similar societies, to representation on the Board of Governors.

Members of the Institute will be able to subscribe to the new journal at privileged rates, details of which will be announced later.

NEWS OF MEMBERS

▶ Mr. H. S. AVERY, of the American Brake Shoe Company, Mahwah, N.J., has been awarded the Lincoln Gold Medal of the American Welding Society for 1952. He was previously the recipient of the same award in 1950.

▶ Mr. B. C. BRUCE-GARDNER, formerly at John Lysaghts Ltd., Scunthorpe, is now with the Patent Shaft and Axletree Co., Ltd., Wednesbury, Staffs.

▶ Mr. D. J. BULLIVANT has left William Redfern Ltd., Manchester. He has been appointed a Director of Shardal Castings Ltd., Birmingham.

▶ Mr. G. J. CATTERALL has been awarded the A.R.S.M. and the degree of B.Sc. of the University of London. He has taken up an appointment with Group Four Metals Ltd., London.

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▶ Mr. L. E. CROOKS has left the Metallurgical Industries Department, B.A.O.R., Düsseldorf, Germany, and is now with B.E.L.A. Metals Ltd., London.
▶ Mr. H. J. DAVIES has left Birmingham University to join Richard Thomas and Baldwins Ltd., Briton Ferry, Neath.
▶ Mr. D. T. ELLIS has given up his position as Chief Metallurgist to Messrs. Jaguar Cars Ltd., Coventry.
▶ Mr. H. M. FABRY has left Poldi Steel Co. (England) Ltd., Sheffield, to join Atlas Steels Ltd. of Canada as their European Representative.
▶ Mr. N. HAWKINS has left the English Electric Co., Ltd., Stafford, to join the British Driver-Harris Co., Ltd., Manchester.
▶ Mr. R. S. HENTHORN has left John Summers and Sons Ltd., Shotton, and is now in charge of the laboratories at Morgan Refractories Ltd., Neston, Cheshire.
▶ Mr. A. JACKSON, Deputy General Works Manager of the Appleby-Frodingham Steel Company, has received a foundation award of the recently established City and Guilds of London Institute Insignia.
▶ Mr. G. J. METCALFE has left the Fulmer Research Institute, Stoke Poges, to take up an appointment as Senior Research Metallurgist in the Precious Metals Division of The Mond Nickel Co., Ltd., Acton.
▶ Mr. B. D. J. OSMENT has been transferred from the Northern Region of the Ministry of Fuel and Power at Newcastle to the Wales Region at Cardiff.
▶ Mr. R. H. PARKER has resigned his appointment at the University College of Swansea, and is now with Guest Keen Baldwins Iron and Steel Co., Ltd., Cardiff.
▶ Mr. T. E. PEACOCK has resigned his post with Swan, Hunter and Wigham Richardson Ltd., Jarrow. He is now taking an honours degree course in Chemistry at King's College, University of Durham.
▶ Mr. S. V. RAMAN, Chief Metallurgist to the National Iron and Steel Co., Ltd., Calcutta, is to visit the U.K. under a Colombo plan award, for six months training at Dorman Long and Co., Middlesbrough.
▶ Mr. M. B. SANDERS has been awarded the degree of B.Sc. in metallurgy of the University College of South Wales and Monmouthshire. He has taken up an appointment with the Bristol Aeroplane Company.
▶ Dr. A. J. SHALER, formerly Associate Professor of Metallurgy at the Massachusetts Institute of Technology, has been appointed Professor of Metallurgy and Chief of the Division of Metallurgy at the Pennsylvania State College, U.S.A.
▶ Mr. C. R. WHEELER, Joint Managing Director of Guest Keen Baldwins Iron and Steel Co., Ltd., has been made a Director of Guest Keen and Nettlefolds Ltd.
▶ Mr. HARRY YATES, President of the Association of British Chambers of Commerce, is a member of the newly established British Productivity Council.

Obituary

Señor ERNEST CRAVATTE, Managing Director of S.A. Talleres Metalurgicos San Martin (TAMET), Buenos Aires, in October, 1952.

Mr. CLEMENT SAXTON, of Northwood, Middlesex, in June, 1952.

CONTRIBUTORS TO THE JOURNAL

H. M. Otte, B.Sc., Ph.D.—Department of Metallurgical Engineering, Case Institute of Technology, Cleveland, Ohio.

Dr. Otte was born in 1929 in Madras, India. He received grammar school education in Birmingham and entered Birmingham University, where he graduated with honours in 1949. He was awarded the degree of Ph.D. in 1952, and is now a Post-Doctoral Fellow at the Metals Research Laboratory of the Case Institute.

A. Taylor, M.I.Mech.E.—Director and Chief Group Engineer of South Durham Steel and Iron Co., Ltd., and Cargo Fleet Iron Co., Ltd.

Mr. Taylor was educated at Verdin School, Winsford, Cheshire, and at the Manchester School of Technology. He was first employed at Imperial Chemical Industries Ltd., Cheshire, in what is now the Salt Division, and in 1917 he joined the Britannia Works of Dorman Long and Co., Ltd., where he became successively Chief Draughtsman and Works Engineer. He was appointed Chief Engineer at the Irlam Works of the Lancashire Steel Corporation Ltd. in 1930, at the commencement of their reconstruction scheme. In 1940 he joined the South Durham Steel and Iron Co., Ltd., as Assistant Chief Group Engineer, and five years later he became Chief Group Engineer. He took up his present appointment in 1950.

A. Taylor

Mr. Taylor is a member of the Institution of Mechanical Engineers, the Northern Regional Fuel Efficiency Advisory Committee, and the Mechanical Engineering and Fuel Committee of the British Iron and Steel Research Association.

E. R. S. Watkin, B.Com.(Transport)—Traffic Manager, Appleby-Frodingham Steel Company. Mr. Watkin was born in London and was educated at Haberdashers' Aske's Hatcham School and at the London School of Economics, where he graduated in 1929. He joined The United Steel Companies Ltd., under their College Apprenticeship Scheme, in 1930, and spent two years at their Workington, Scunthorpe, Rotherham, and Stocksbridge Works. He returned to the Scunthorpe Works in 1932 as Assistant Traffic Manager, and became Traffic Manager in 1939.

J. H. van der Veen, D.Sc.—Physical Metallurgist, Research Department of the Royal Netherlands Blast Furnaces and Steelworks, Ijmuiden.

Dr. van der Veen was born in 1912 and was educated at the University of Utrecht, where he studied physics and mathematics. In 1935 he became Assistant for Experimental Physics in the Utrecht Physical Laboratory, under the Directorship of Professor L. S. Ornstein. He obtained the degree of M.Sc. in 1936, and in 1938 was awarded the degree of D.Sc. for a thesis on the behaviour of the reflecting power of iron for visible light in the neighbourhood of the Curie-point and α/γ-transition point. He was then appointed Physicist in the Amsterdam Laboratory of the Royal Dutch Shell-group, where he studied physical methods of oil refining and the

E. R. S. Watkin

J. H. van der Veen

viscosity of liquids. He took up his present appointment in 1946.

Dr. van der Veen is a member of the Research Committee and Council of the Netherlands Centre for Welding Technique.

S. J. Smith, A.I.M.—Works Metallurgist, Stewarts and Lloyds Ltd., Corby.

Mr. Smith was educated at King Edward's Grammar School, Aston, and at Birmingham Technical College. He commenced his career in 1935, in the Research Laboratories of I.C.I. Metals Division, Birmingham. In 1939 he joined the Research Laboratories of Stewarts and Lloyds Ltd., and three years later he transferred to their Steelworks as Technical Assistant to the Steelworks Manager. He took up his present appointment in 1947.

Mr. Smith is at present serving on the Rolling Ingots and Ingot Moulds Sub-Committees of the British Iron and Steel Research Association.

IRON AND STEEL ENGINEERS GROUP

The **Twenty-First Meeting** of the Iron and Steel Engineers Group will be held jointly with the Plant Engineering and Steel Making Divisions of the British Iron and Steel Research Association on **Wednesday, 21st January, 1953.**

The Meeting will be held at the Institution of Mechanical Engineers, Storey's Gate, London, S.W.1, and will be devoted to the presentation and discussion of four papers on British and Overseas Practice in the Maintenance and Repair of Open-Hearth Furnaces.

A Buffet Luncheon will be held at the Institution of Mechanical Engineers in connection with the Meeting.

All Members of the Institute, whether Members of the Engineers Group or not, and all Members of the Staff of Member Firms of the British Iron and Steel Research Association will be welcome at the Meeting. They may bring guests with them to the Meeting and Luncheon.

The following is the detailed programme:

9.30 A.M.–12.0 NOON—*British Practice.* Joint Discussion on:

"*Cold Metal Practice for Fixed* 80- *to* 100-*ton Furnaces,*" by J. E. Pluck (Steel, Peech and Tozer, Ltd.)

"*Hot Metal Practice for* 80-*ton Fixed and* 250-*ton Tilting Furnaces,*" by S. G. Williams (Guest Keen Baldwins Iron and Steel Co., Ltd.)

12.0 NOON–1.30 P.M.—Buffet Luncheon

1.30–4.0 P.M.—*Overseas Practice.* Joint Discussion on:

"*Repair and Maintenance of Open-Hearth Furnaces in U.S.A.,*" by R. W. Evans and I. S. Scott-Maxwell (Steel Company of Wales, Ltd.)

"*Repair and Maintenance of Open-Hearth Furnaces in Germany,*" by C. Kreutzer and A. Mund (Maerz Ofenbau GmbH., Krefeld, Germany)

Copies of the papers, in stencilled form, will be circulated beforehand to all those wishing to attend the Meeting; they will be published in the *Journal* in due course, together with a report of the discussion.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION

The Fight Against Rust

The Corrosion Committee has recently produced a booklet entitled "*The Fight Against Rust,*" which gives an account of the work of the Committee and some of its most important findings.

Seven case histories are given, with photographs, to illustrate the effects of corrosion by air, water, and soil. The results of field tests on specimens of irons and steels, bare or with a protective coating, exposed to such corrosion are discussed and some are given in graphical form. The two main types of protection, by paints or by metallic coatings, are described, together with a note on two new methods of testing the efficiency of such protection. Finally, a brief survey is made of the fundamental research on corrosion which is being carried out at Cambridge University (under Dr. Evans) and at the Chemical Research Laboratory, Teddington (under Dr. Vernon).

The Committee conclude that prevention of corrosion is possible by one or more of four methods: (i) deliberate alterations in the corrosive medium; (ii) modification in the design of plant or apparatus exposed to corrosion; (iii) changes in the composition of the steel; and (iv) efficient protective measures. Essential features of the latter are the correct surface preparation of the steel, priming paint of an inhibitive character, and adequate coating thickness.

The booklet, price 2*s.* 6*d.*, is obtainable from the British Iron and Steel Research Association, 11 Park Lane, London, W.1.

20th Blast-Furnace Conference

The Twentieth Blast-Furnace Conference of the Association was held at Ashorne Hill on 28th and 29th October, 1952. The Chair was taken by Mr. W. C. Bell (Chairman of the Iron Making Divisional Panel) supported by Mr. R. P. Towndrow (Chairman of the Blast-Furnace Practice Committee) and Dr. H. L. Riley (Chairman of the Blast-Furnace Process Committee). There were 93 Members present.

Sir Charles Goodeve (leader of the Anglo-American Productivity Team on Iron and Steel) introduced the Iron Making Section of the Team's Report. This section formed the basis of the main item discussed: "Factors Influencing the Driving Rate of British Blast-Furnaces."

Prepared contributions were submitted by 10 Members, giving details of the driving rates appertaining to various current practices. In discussion, statistical and practical considerations were presented in relation to fuel economy. A further session was devoted to discussion of furnace size, burden preparation, blast-furnace coke, and the size of foundry iron furnaces.

INSTITUTE OF METALS

The following members have been elected to fill vacancies on the Council, with effect from the Annual General Meeting, 1953:

President: Professor F. C. THOMPSON

Vice-Presidents: Major C. J. P. BALL, Professor G. V. RAYNOR

Members of Council: Mr. W. A. BAKER, Mr. E. R. GADD, Mr. J. C. COLQHOUN, The Hon. John GRIMSTON, M.P.

The Council of the Institute has elected Dr. S. F. Dorey to serve as Senior Vice-President for 1953–54, and he will be their nominee for the Presidency in 1954–55.

Students' Essay Prize Competition, 1953

The Council of the Institute of Metals will again present prizes of 20 guineas each for the best two essays submitted in accordance with the regulations. The choice of subject on non-ferrous metallurgy is left to the competitors; subjects relating exclusively to extraction or ferrous metallurgy are excluded.

Details of the prizes and of eligibility for the competition will be found on p. 377 of the April, 1952, issue of the *Journal*, and further information may be obtained from the Secretary, The Institute of Metals, 4 Grosvenor Gardens, London, S.W.1.

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AFFILIATED LOCAL SOCIETIES

Cleveland Institution of Engineers

The list of Officers for the Session 1952–53 is as follows:

President

F. KENNEDY

Vice-Presidents

A. DORMAN — E. W. JACKSON
R. MATHER

Members of Council

N. BLANEY — E. DREWERY
H. H. UTLEY — T. W. HURST
W. W. STEVENSON — H. M. MORGAN
T. W. THURSFIELD — E. F. BROWN
W. R. BROWN — E. EASON
T. H. STAYMAN

Members of Council (Past-Presidents)

A. SCHOLES — F. SHEPHERD
J. H. PATCHETT — E. T. JUDGE
C. MOODY — G. B. THOMAS
N. C. LAKE

Hon. General Secretary and Treasurer

F. G. E. WEBSTER

Hon. Technical Secretary

L. STEPHENSON

Ebbw Vale Metallurgical Society

The list of Officers for the Session 1952–53 is as follows:

President

W. D. JENKINS, B.Sc.

Vice-President

A. W. ELLIS

Hon. Treasurer

H. EVANS

Hon. Joint Secretaries

W. B. WILLIAMS — R. C. POWELL, B.Sc.

Committee

J. J. BEESE — F. LLEWELLYN
W. H. R. BIRD, M.A., B.Sc. — D. A. JENKINS
W. J. DAVIES — J. F. SMITH
E. K. EDWARDS, M.A. — I. GIDDINGS
P. EDWARDS — J. T. MILLS
A. J. MEO — F. E. PROBYN
F. W. LEWIS — Dr. G. R. PARKES
H. F. PADBURY — W. E. WILLIAMS

The following programme has been arranged for the present Session:

6th Jan.—"*Some Modern Civil Engineering Plant and its Operation.*" by P. J. F. Stuart.
"*The Structure of Metals,*" by J. Thickins.

3rd Feb.—"*Steel Works Electrical Equipment and its Maintenance,*" by J. T. Mills.

25th Mar.—(Joint Meeting with The Iron and Steel Institute)—"*Deep Drawing,*" by H. W. Swift.

26th Mar.—Annual Dinner.

Leeds Metallurgical Society

The list of Officers for the Session 1952–53 is as follows:

President

Dr. N. J. PETCH

Past-Presidents

F. K. NEATH — G. W. GREEN
J. WILKINSON

Vice-Presidents

H. F. POOLE — H. D. WARD

Hon. Treasurer

D. E. CATTON

Hon. Secretary

Dr. K. J. IRVINE

Committee

C. E. BURRELL — A. LENTON
Dr. W R. BERRY — F. LINDARS

Liverpool Metallurgical Society

The list of Officers for the Session 1952–53 is as follows:

President

R. S. BROWN, M.B.E.

Vice-President

H. J. MILLER, M.Sc.

Hon. Secretary

S. V. RADCLIFFE, B.Eng.

Hon. Treasurer

G. T. CALLIS, B.Sc.

Committee

H. EDWARDS — S. J. KENNETT, B.Sc., Ph.D.
T. H. FLETCHER — J. J. MILES
A. E. GRIFFIN — R. S. MOORE

The following meetings have been arranged for the present Session:

8th Jan.—Open Discussion.

21st Jan.—(Joint Meeting with the North Wales Metallurgical Society) "*Alloys Resistant to Oxidation and Creep at High Temperatures,*" by S. J. Kennett. (To be held in the County Primary School, Plymouth Street, Shotton, Nr. Chester, at 7.15 P.M.).

12th Feb.—"*Nucleation in Metals and Alloys,*" by J. H. O. Varley.

25th Feb.—Visit to the British Aluminium Co., Ltd., Warrington.

12th Mar.—"*The Use of Aluminium in Shipbuilding and Structural Engineering,*" by E. G. West.

9th Apr.—(Joint Meeting with The Iron and Steel Institute) Annual General Meeting. "*The Basic Processes Involved in the Tempering of Plain Carbon and Low Alloy Steels,*" by W. S. Owen.

15th Apr.—Visit to Lever Brothers Ltd., Port Sunlight.

All lectures, with the exception of that on 21st January, 1953, will be held at the Liverpool Engineering Society, The Temple, Dale Street, Liverpool, at 6.30 P.M.

The Hon. Secretary is now Mr. S. V. Radcliffe, B.Eng., 55 Tudorville Road, Bebington, Cheshire.

Manchester Metallurgical Society

The list of Officers for the Session 1952–53 is as follows:

President

H. ALLISON, B.Sc.(Tech.)

Ex-President

A. B. ASHTON, M.Sc.

Vice-Presidents

W. B. WRAGGE, B.Sc.(Tech.) J. D. HANNAH, M.Sc.
C. J. BUSHROD, M.Sc.

Hon. Treasurer N. YOUATT

Hon. Secretary J. A. TOD, B.Sc.

Council

G. A. COTTRELL, M.Sc. — F. H. POOLE, A.M.C.T.
E. HOLLAND, B.Sc. — R. WALLACE
K. M. ENTWISTLE, M.Sc., Ph.D. — W. H. N. WHYMAN, B.Sc.
V. B. HYSEL, M.Sc.
E. L. FRANCIS, M.Sc. — J. Y. DAVIES, B.Sc.

The following meetings have been arranged:

7th Jan.—(Joint Meeting with The Iron and Steel Institute) "*The Manufacture of Large Forgings including Crankshafts made by the C.G.F. Process*," by H. H. Burton.
21st Jan.—"*Indentation Hardness*," by D. Tabor.
4th Feb.—"*Some New Laboratory Techniques*," by F. Ashworth, F. G. Haynes, and J. Johnson.
18th Feb.—"*Metallurgical Aspects of Lubricating Problems*," by A. L. H. Perry.
4th Mar.—"*Precipitation Hardening*," by H. K. Hardy.
18th Mar.—Visit to the Froghall Works, Staffordshire, of Messrs. Thomas Bolton and Sons, Ltd.

All lectures will be held in the Engineers' Club, Albert Square, Manchester, at 6.30 P.M.

Newport and District Metallurgical Society

The following Meetings have been arranged:

15th Jan.—(Joint Meeting with the Institute of British Foundrymen) "*The Metallurgical Problems Associated with the Manufacture of Spun Cast Iron Pipes*," by R. V. Riley.
12th Feb.—"*The Presentation of Data and Industrial Efficiency*," by B. Dudding.
24th Feb.—Visit to the Trostre Works of The Steel Company of Wales, Ltd.
3rd Mar.—"*Flat Rolled Products*," by S. E. Graeff.
29th Apr.—Visit to the Atomic Energy Research Establishment, Harwell.

All lectures will be held at the Whitehead Institute, Cardiff Road, Newport, at 7.0 P.M.

Sheffield Society of Engineers and Metallurgists

The list of Officers for the Session 1952–53 is as follows:

President

GEORGE BAKER, O.B.E.

Vice-Presidents

E. D. BOOL — L. K. EVERITT
H. BULL — R. E. S. FISHER
Professor R. J. SARJANT

Members of Council

H. H. BURTON — Dr. W. R. MADDOCKS
M. A. FIENNES — J. A. MCWILLIAM
W. W. FRANKLIN — Professor A. G. QUARRELL
G. E. GILFILLAN — F. H. SANITER
Dr. E. GREGORY — Dr. C. SYKES
W. A. JOHNSON — J. WOOLMAN

EDUCATION

Insignia Award in Technology

The City and Guilds of London Institute proposes to establish under its Royal Charter an Insignia Award in Technology. The object of this Award, which will be at a higher level than that of the Full Technological Certificates, is to give additional encouragement and recognition to those engaged in industry who continue to pursue their studies and broaden their knowledge.

At the Annual Meeting of the City and Guilds Institute held at Goldsmith's Hall, foundation awards of the insignia were presented by the Duke of Edinburgh to Mr. A. Jackson, for ferrous metallurgy, and to Sir Arthur Smout, for non-ferrous metallurgy.

Further details may be obtained from the Director, Department of Technology (I.A.), City and Guilds of London Institute, 31 Brechin Place, South Kensington, London, S.W.7.

Whitworth Scholarships

The Minister of Education, as Trustee of the Foundation of Sir Joseph Whitworth, will offer for competition in 1953 two Whitworth Senior Scholarships of the value of £325 per annum, tenable for two years, and five Whitworth Scholarships of the value of £200, tenable for three years. Further prizes of £20 each will be awarded to not more than 10 candidates whose work deserves recognition. The awards are intended to enable the holders to pursue their studies in engineering, and successful candidates must have the Minister's approval of their proposals for holding Scholarships or spending prize money.

Full details of the awards and syllabus of the examination are given in "Regulations and Syllabus for Whitworth Scholarships, 1951" which may be obtained from H.M.S.O., York House, Kingsway, London, W.C.2, price 4*d*. (by post 5½*d*.). Closing date for receipt of entry forms is 15th January, 1953.

The United Steel Companies Ltd.

A recent booklet published by The United Steel Companies Ltd., entitled "The Recruitment and Training of Senior Staff," outlines the Companies' policy in relation to the selection and training of personnel for the higher executive grades in their organization. The three categories of senior staff—senior executives, intermediate management, and junior management—are recruited from within the organization and outside. The Companies encourage their technical apprentices to study for the recognized technical qualifications of the professional institutions and for external degrees, with a view to promotion to the senior grades. In addition, special apprentices, with public or secondary school education or university degrees, are selected from outside the organization to be trained for appropriate senior posts. Their training course is very comprehensive, and includes several months' shop-floor work. At the end of this period, the trainees' capabilities have been assessed sufficiently for them to be allocated to the branch—general, engineering, or scientific—to which they are best suited.

Institute of Technology, Loughborough College

The Minister of Education has decided to relieve the Leicestershire Local Education Authority of its responsibility for maintaining the Engineering and Science Departments of Loughborough College. They are to be reorganized as a separate establishment, maintained largely by Exchequer grant, with the title of the Institute of Technology, Loughborough College. This will be administered by a governing body under the chairmanship of Sir Harold West, managing director of Newton, Chambers and Co., Ltd., Sheffield.

Loughborough College has a considerable reputation for the training of engineers, and the new Institute hopes

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to be able to continue this tradition. It will teach all branches of engineering, facilities for which will be improved when the new laboratories come into use in about a year's time.

International Exchange of Technical Students

The 5th Annual Report of the International Association for the Exchange of Students for Technical Experience (I.A.E.S.T.E.) gives full details of a very successful year. There are now 17 countries participating in the scheme, which was initiated in 1948 with the object of facilitating the exchange of students for practical experience in industry abroad. During 1952, the British central office sent 488 British students overseas and in return received 602 foreign students, who gained practical experience of British industry and commerce. The General Secretary of the Association is Mr. P. Newby, Imperial College, South Kensington, London, S.W.7 (Kensington 4861).

Joint Committee on Metallurgical Education

In an announcement in the News Section of the December, 1952, issue of the *Journal*, details were given of the latest report of the Joint Committee, entitled "*The Education and Training of Metallurgists.*" The following is a summary of the Committee's recommendations:

(1) The Universities are at present, are likely to be, and should continue to be, the chief source of high-grade technologists. Universities should expand their output of technologists to the greatest extent they can achieve.

(2) Employers should finance the attendance of suitable employees at post-graduate courses in universities.

(3) Formally established methods should be adopted for training graduates immediately they enter industry.

(4) Since more technologists are needed than the universities can supply, the remainder coming from colleges of technology, a few colleges of technology should be upgraded and equipped for the education of high-grade technologists.

(5) In high-grade, technical teaching institutions, instruction in technical and elementary subjects should be physically separated from that in higher technological subjects.

(6) The present standard of staffing in technical colleges and colleges of technology should be raised.

(7) There should be active collaboration in various fields between colleges of technology and employers.

(8) The whole of the present examinations in metallurgy for non-university students should be considered with a view to their co-ordination and rationalization and the establishment of the Associateship of the Institution of Metallurgists as the normal goal for almost all such students.

(9) Further provision for sandwich courses should be made.

(10) Since it appears that operatives in the metallurgical industries are insufficiently responsive to the opportunities offered for education and training, the greater use of incentives should be examined; employers should take into account any examination successes by their employees when considering promotion and the filling of vacancies in operational departments.

(11) To achieve a balance in the education of metallurgists, all teaching establishments—including the universities—and employers are recommended to instruct students and employees in the new humanities.

The Committee will be pleased to have comments on the report and on the recommendations made in it. These will be given careful attention.

NEWS OF SCIENCE AND INDUSTRY

Protective Coatings Symposium

A symposium on protective coatings has been arranged for the Ninth Annual Meeting of the National Association of Corrosion Engineers, to be held in Chicago on 16th–20th March, 1953.

Fifth Empire Mining and Metallurgical Congress

The Fifth Empire Mining and Metallurgical Congress is being held in Australia and New Zealand during April and May, 1953. The main section of the technical proceedings will take the form of a series of eight volumes describing the mineral deposits and the mining and metallurgical practices in Australia, New Zealand, and surrounding territories. Brief details of each volume are as follows:

Volume I—"*Geology of Australian Ore Deposits*" (1100 pp.)—Descriptions of the important productive orebodies of Australia, with emphasis on features of structural control.

Volume II—"*Mining Methods in Australia and Adjacent Territories*" (350 pp.)—Survey of the application and adaptation of accepted methods of mining and development for orebodies and alluvial deposits in Australia, New Guinea, and Fiji.

Volume III—"*Ore Dressing Methods in Australia and Adjacent Territories*" (350 pp.)—Methods in use in Australia, New Guinea, and Fiji, with comments on factors affecting the choice of process. Sections relate to lead–zinc, copper, gold, tin, tungsten, beach sands, etc.

Volume IV—"*Extractive Metallurgy in Australia*" (400 pp.)—The smelting, hydrometallurgical, and other processes used in the production of iron, steel, and various metals and alloys. Also covers the utilization of sulphur in Australian ores for contact and chamber sulphuric acid.

Volume V—"*Australian Mining and Metallurgy*" (300 pp.)—Ventilation, safety, hygiene, mining and industrial regulations, education, training, and research.

Volume VI—"*Coal in Australia*" (750 pp.)—Geology and physical characteristics of seams and coals, with sociological and financial aspects.

Volume VII—"*Handbook—Australia and New Zealand*" (250 pp.)—Official guide to Australia and New Zealand, with particular reference to the mining and metallurgical industries.

Volume VIII — "*Proceedings and New Zealand Papers*"—Available towards the end of 1953.

Full particulars of the tours, time table, costs, etc., may be obtained from the Secretary, Fifth Empire Mining and Metallurgical Congress, 399 Little Collins Street, Melbourne, Australia.

Second International Congress on Rheology

The British Society of Rheology, supported by the Joint Commission on Rheology of the International Council of Scientific Unions, is holding the 2nd International Congress on Rheology at St. Hilda's College, Oxford, on 26th–31st July, 1953.

The Congress will cover the whole field of the study of the deformation and flow of matter, except such specialized subjects as are now regarded as branches of applied mechanics, *e.g.*, the classical theory of elasticity, and aerodynamics. The programme will include a Presidential Address, a number of invited lectures, and a discussion on the International Organization of Rheology.

Full particulars may be obtained from the Organizing Secretary, Dr. G. W. Scott Blair, The University, Reading, England.

French Steel Research Institute

The French Steel Research Institute (IRSID) has been inaugurated by M. Schuman, Foreign Minister, and M. Louvel, Minister of Industry. IRSID, which has an ore-testing plant at Saulnes (E. France) and an experimental coking plant at Marienan (E. France), is co-operating with similar foreign institutions. Part of its programme is concerned with the improvement of basic Bessemer steel.

American Society for Testing Materials

The American Society for Testing Materials, through its President, Harold L. Maxwell, has announced the election of Robert J. Painter as Executive Secretary of the Society, and of Raymond E. Hess as Associate Executive Secretary and Editor-in-Chief.

Institution of Mining and Metallurgy

The Council of the Institution of Mining and Metallurgy have announced the election of Professor J. A. S. Ritson, O.B.E., D.S.O., M.C., as President for the Session 1953–54. He will take office at the General Meeting to be held on 28th May, 1953.

British Productivity Council

The British Productivity Council has now been formally established. The new organization is on a broader basis than its predecessor, the U.K. Section of the Anglo-American Council on Productivity, whose work it is taking over in addition to engaging in fresh activities. Sir Peter Bennett, O.B.E., M.P., Past-President of the F.B.I., has been appointed Chairman of the Council, and Mr. Lincoln Evans, C.B.E., General Secretary of the Iron and Steel Trades Confederation, is Deputy Chairman.

World Power Conference, 1952

The new edition of the list of National Committees and Representatives of the World Power Conference has recently been published. Copies may be obtained from the offices of the British National Committee, World Power Conference, 201–2 Grand Buildings, Trafalgar Square, London, W.C.2, at 1*s.* 6*d.* per copy, post free.

Annual Report of Ministry of Labour, 1951

The Annual Report of the Ministry of Labour and National Service, which reviews the work of the Ministry for the year 1951, has now been published. The Report gives details of manpower in civil employment and in H.M. Forces, and reference is made to industrial and international labour relations.

The Report, Cmd. 8640, is published by H.M.S.O., price 6*s.* 3*d.* post free.

Research in Universities

"*Scientific Research in British Universities*, 1951–2," published by H.M.S.O. for the Department of Scientific and Industrial Research, gives details of research work in Universities and Colleges in the United Kingdom. It covers all fields of science and technology, including agriculture and medicine.

It is hoped that the list will henceforth be an annual publication.

Metallurgical Equilibrium Diagrams

A monograph on "Metallurgical Equilibrium Diagrams," by W. Hume-Rothery, J. W. Christian, and W. B. Pearson, has been published by the Institute of Physics. A full account is given of the experimental techniques used for determining the liquidus, the solidus, and solid solubility curves. The use of X-ray methods is described, and ternary systems are dealt with from both the theoretical and the experimental viewpoints.

Mining Collection at the Science Museum

The Mining Collection at the Science Museum has now been reopened in much enlarged form. The basic conception of the new design is to give the impression of being underground in the actual workings of a mine. Various sub-sections illustrate the historical development of many ancillary mining services such as transport, winding, boring and sinking, lighting, ventilation, and rescue work.

Metalwork in Secondary Schools

Ministry of Education Pamphlet No. 22, entitled "*Metalwork in Secondary Schools*," has been published by H.M.S.O. (price 3*s.* 6*d.*). It deals with the organization of metalwork teaching, and suggests schemes of instruction for various types of schools and workshops.

Blast-Furnace Relined in Record Time

On 27th September, 1952, No. 9 blast-furnace at the Appleby-Frodingham branch of The United Steel Companies, Ltd., was taken off wind. On October 20th, 24 days later, it was relit, having been relined and enlarged. This constitutes a world record time, and is 96 days better than the national average time of 120 days. It is estimated that this rapid operation, the success of which was due to meticulous planning and ingenious use of existing machinery, has made available an additional 58,000 tons of pig iron.

New Ceramic Coatings

The Solar Aircraft Company, San Diego, California, are now manufacturing new ceramic coatings for ordinary steels that will allow them to be used in place of alloys rich in scarce elements.

Industrial Publications Received

▶ "Oxygen in Steelmaking: The Electric Arc Furnace" is the second of a series of brochures, published by the British Oxygen Co., Ltd., on the use of oxygen in steelmaking furnaces. Details of the procedure and oxygen requirements are given, and three typical oxygen installations are illustrated. In the manufacture of both plain-carbon and high-chrome steels, the main advantages of oxygen treatment are the saving of power and an increased output from the furnace. In stainless steel manufacture, oxygen is effective in melting and clearing scrap, and 100% scrap charges can now be worked.

▶ "Metacon 516," A Concentrated Rust Remover and Short-Term Anti-Corrosive Treatment—Croda Ltd.

▶ Continuous Flow Balanced Hearth Walking Beam Furnaces—Bulletin No. V.13, the Incandescent Heat Co., Ltd.

▶ Clean Rapid Heating for Forging and Upsetting—Catalogue No. 85, Birlec Ltd.

▶ An 8-page booklet entitled "The Properties of Fullers' Earth and Some Uses of Fullers' Earth Products" has been produced by the Fullers' Earth Union Ltd., Redhill, Surrey. Details of the crystal structure and the colloidal, physico-chemical, and physical properties are given, together with the main commercial applications of fullers' earth products. Some of these products are described in more detail in booklets entitled "Notes on Fulbonds for Foundry Sands," "The Moulding Properties of Fulbond at Higher Moistures," and "Notes on Fulbent."

DIARY

5th Jan.—CLEVELAND INSTITUTION OF ENGINEERS—"*Operation of Blast Furnaces at Clyde Ironworks at High Top Pressure*," by R. P. Towndrow—Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, 6.30 P.M.

5th Jan.—INSTITUTE OF BRITISH FOUNDRYMEN—Discussion on "*Methods of Making a Typical Casting in Iron, Steel and Non-Ferrous Metal*"—Sheffield College of Commerce and Technology, Department of Engineering, Pond Street, Sheffield 1, 7.30 P.M.

6th Jan.—EBBW VALE METALLURGICAL SOCIETY—"*Some Modern Civil Engineering Plant and its Operation*," by P. J. F. Stuart, and "*The Structure of Metals*," by J. Thickins—Lecture Room, Richard Thomas and Baldwins Ltd., Ebbw Vale, 7.15 P.M.

6th Jan.—SHEFFIELD METALLURGICAL ASSOCIATION—Résumé of Papers presented at the 6th Chemists' Conference, Ashorne Hill, 1952—Grand Hotel, Sheffield, 7.0 P.M.

7th Jan.—MANCHESTER METALLURGICAL SOCIETY (Joint Meeting with The Iron and Steel Institute)—"*The Manufacture of Large Forgings including Crankshafts made by the C.G.F. Process*," by H. H. Burton—Engineers' Club, Albert Square, Manchester, 6.30 P.M.

7th Jan.—INSTITUTE OF WELDING—"*Recent Developments in Argonarc Welding*," by W. A. Woolcott—College of Technology, Manchester, 7.15 P.M.

8th Jan.—INSTITUTE OF WELDING—"*Some Experiences in the Metallurgy of Hard Surfacing*," by E. Bishop—Caxton Hall, Caxton Street, Victoria, London, S.W.1, 6.30 P.M.

8th Jan.—LEEDS METALLURGICAL SOCIETY—Film Night—Chemistry Department, The University, Leeds 2, 7.0 P.M.

8th Jan.—LIVERPOOL METALLURGICAL SOCIETY—Open Discussion—Liverpool Engineering Society, The Temple, Dale Street, Liverpool, 6.30 P.M.

9th Jan.—INSTITUTION OF MECHANICAL ENGINEERS—"*Control Valves for Direct-Hydraulic Presses*," by F. H. Towler and J. M. Towler—Storey's Gate, St. James's Park, London, S.W.1, 5.30 P.M.

10th Jan.—SWANSEA AND DISTRICT METALLURGICAL SOCIETY—"*Metallic Coating on Steel*," by D. L. Phillips—Central Library, Swansea, 6.30 P.M.

12th Jan.—INSTITUTION OF PRODUCTION ENGINEERS—"Photo-Elasticity," by H. T. Jessop—Royal Victoria Station Hotel, Sheffield, 6.30 P.M.

12th Jan. — JUNIOR INSTITUTION OF ENGINEERS — "*Science Looks at Works Corrosion*," by H. G. Gow—Livesey Clegg House, Sheffield, 7.30 P.M.

15th Jan.—NEWPORT AND DISTRICT METALLURGICAL SOCIETY (Joint Meeting with Institute of British Foundrymen)—"*The Metallurgical Problems Associated with the Manufacture of Spun Cast Iron Pipes*," by R. V. Riley—Whitehead Institute, Cardiff Road, Newport, 7.0 p.m.

15th Jan.—STAFFORDSHIRE IRON AND STEEL INSTITUTE—"*Some Factors Affecting Productivity in a Cold Metal Steel Melting Shop*," by W. S. Walker—Round Oak Steelworks, Dudley, 7.30 P.M.

19th Jan.—SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS—"*The Application of the Diesel Engine and the Gas Turbine to Traction*," by G. H. Fletcher—The University Building, St. George's Square, Sheffield, 7.30 P.M.

20th Jan.—CLEVELAND INSTITUTION OF ENGINEERS—"*Organising and Commissioning the New Rolling Mills of the Steel Company of Wales, Ltd.*," by H. Ascough, and Film "*The First Four Years*"—Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, 6.30 P.M.

20th Jan.—SOCIETY OF CHEMICAL INDUSTRY—"*The Electrochemical Behaviour of Metals and Corrosion*," by M. Pourbaix—Chemical Society, Burlington House, London, W.1, 6.30 P.M.

20th Jan.—LINCOLNSHIRE IRON AND STEEL INSTITUTE—"*Some British Aspects of High Top Pressure Operation*," by R. P. Towndrow—Wortley Hotel, Scunthorpe, 7.30 P.M.

21st Jan.—INSTITUTE OF FUEL—Selected Paper on "*Special Study of Ash and Clinker in Industry*"—The University of Sheffield, 6.30 P.M.

21st Jan.—IRON AND STEEL ENGINEERS GROUP (Joint Meeting with British Iron and Steel Research Association)—Twenty-First Meeting—Institution of Mechanical Engineers, Storey's Gate, London, S.W.1, 9.30 A.M.

21st Jan.—NORTH WALES METALLURGICAL SOCIETY (Joint Meeting with Liverpool Metallurgical Society)—"*Alloys Resistant to Oxidation and Creep at High Temperatures*," by S. J. Kennett—County Primary School, Plymouth Street, Shotton, Nr. Chester, 7.15 P.M.

21st Jan.—MANCHESTER METALLURGICAL SOCIETY—"*Indentation Hardness*," by D. Tabor—Engineers' Club, Albert Square, Manchester, 6.30 P.M.

22nd Jan.—INSTITUTION OF PRODUCTION ENGINEERS—"*Recent Developments in Metal Machining*," by K. J. B. Wolfe—Royal Empire Society, Northumberland Avenue, London, W.C.2, 7.0 P.M.

26th Jan.—NORTH EAST METALLURGICAL SOCIETY—Discussion on "*The Training of a Metallurgist*"—Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, 7.15 P.M.

27th Jan.—SHEFFIELD METALLURGICAL ASSOCIATION—"*Hydrogen in Steel: A General Survey*," by K. C. Barraclough—Grand Hotel, Sheffield, 7.0 P.M.

29th Jan.—STAFFORDSHIRE IRON AND STEEL INSTITUTE—"*Ore Preparation*," by G. D. Elliot and N. D. Macdonald—Dudley and Staffordshire Technical College, Dudley, 7.30 P.M.

TRANSLATION SERVICE

(The previous announcement was made in the December, 1952, issue of the *Journal*, p. 430.)

TRANSLATION AVAILABLE

No. 458 (German). H. FLASCHKA and F. HUDITZ: "Rapid Determination of Calcium in Magnesites." (*Radex-Rundschau*, 1952, No. 4, pp. 181–185). (Translation prepared by Mr. U. Weigert and made available by courtesy of The United Steel Companies, Ltd., Research and Development Department, Rotherham).

TRANSLATION IN COURSE OF PREPARATION

(German). K. BORN and W. KOCH: "Influence of Aluminium on the Properties of Mild Unalloyed Steels." (*Stahl und Eisen*, 1952, vol. 72, Oct. 9, pp. 1268–1277).

CHARGES FOR COPIES OF TRANSLATIONS—The charge for translations is £1 for the first copy and 10*s*. for each additional copy of the same translation. Requests should be accompanied by a remittance. These translations are not available on loan from the Joint Library.

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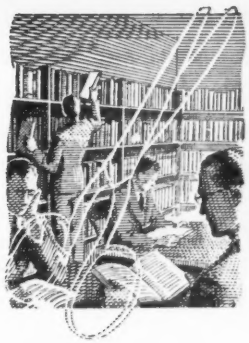
ABSTRACTS AND BOOK NOTICES



IRON AND STEEL MANUFACTURE AND RELATED SUBJECTS

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ABBREVIATIONS AND LIST OF PERIODICALS EXAMINED BY THE ABSTRACTING SERVICE

Acciaio Inossidabile (Milan)
Acero y Energia (Barcelona)
Acid Open Hearth Research Association, Bulletin (Pittsburgh)
Aciers Fins et Speciaux Français (Paris)
Acta Crystallographica (London)
Acta Polytechnica (Stockholm)
Acta Technica (Budapest)
Advancement of Science (London)
Advances in Physics (London)
Aeroplane (London)
Aircraft Engineering (London)
Aircraft Production (London)
Alloy Castings Bulletin (New York)
Alloy Metals Review (Widnes)
Alluminio (Milan)
Aluminium (Budapest)
Aluminium (Düsseldorf)
Aluminium Development Association, Information Bulletin (London)
American Electroplaters' Society, Research Reports (Jenkintown, Pa.)
American Foundryman (Chicago)
American Foundrymen's Society, Preprint (Chicago)
American Institute of Mining and Metallurgical Engineers (New York)
Blast Furnace and Raw Materials Committee
Proceedings Electric Furnace Steel Conference
Proceedings National Open-Hearth Committee
Proceedings Symposia Series
American Iron and Steel Institute (New York)
Annual Statistical Report
Contributions to the Metallurgy of Steel
Steel Products Manual
American Journal of Physics (New York)
American Society for Metals, Preprint (Cleveland, Ohio)
American Society for Testing Materials (Philadelphia)
Preprint
Special Technical Publication
Anais da Academia Brasileira de Ciencias (Rio de Janeiro)
Anais da Associação Química do Brasil (Rio de Janeiro)
Anales da la Asociacion Química Argentina (Buenos Aires)
Anales de la Real Sociedad Española de Fisica y Química (Madrid)
Anales de Mecanica y Electricidad (Madrid)
Analyst (London)
Analytica Chimica Acta (New York and Amsterdam)
Analytical Chemistry (Washington)
Annales des Mines (Paris)
Annales de la Société Scientifique de Bruxelles (Brussels)
Annual Proceedings of the Sheet and Strip Metal Users Technical Association (London)
Annual Report of the Smithsonian Institution (Washington)
Applied Mechanics Reviews (New York)
Applied Research Laboratories, Reports (Glendale, Calif.)
Applied Scientific Research (The Hague)
Applied Statistics (London)
Archiv für das Eisenhüttenwesen (Düsseldorf)
Arkiv för Fysik (Stockholm)
Arkiv för Kemi (Stockholm)
Arkiv för Mineralogi och Geologi (Stockholm)
Arts et Manufacturers (Paris)
Atomics (London)
Atti della Accademia Nazionale dei Lincei. Rendiconti della Classe di Scienze Fisiche, Matematiche e Naturali (Rome)
Australasian Engineer (Sydney)
Australasian Plating and Finishing (Melbourne)
Australian Foundry Trade Journal (Sydney)
Australian Journal of Applied Science (Melbourne)
Australian Journal of Scientific Research (Melbourne)
Automobile Engineer (London)
Avtogennoe Delo (Moscow)

B.H.P. Review (Melbourne)
Ball Bearing Journal (Luton)
Beama Journal (London)
Bell Laboratories Record (New York)
Bell System Technical Journal (New York)
Bell Telephone Laboratories Technical Publication (New York)
Bell Telephone Magazine (New York)
Berg- und hüttenmännische Monatshefte (Vienna)
Betrieb und Fertigung (Vienna)
Bibliographical Bulletin of Welding (Paris)
Blad for Bergshandterigens Vänner (Stockholm)
Blast Furnace and Steel Plant (Pittsburgh)
Boletim da Associação Brasileira de Metais (São Paulo)

LIST OF PERIODICALS

Boletim da Associação Química do Brasil (Rio de Janeiro)
Boletim da Sociedade Geológica de Portugal (Oporto)
Boletin de Informacion del Instituto de la Soldadura (Madrid)
Boletin del Instituto Geológico y Minero de España (Madrid)
Boletim do INT (Rio de Janeiro)
Boletin Minero e Industrial (Bilbao)
Brennstoff-Wärme-Kraft (Düsseldorf)
British Cast Iron Research Association, Journal of Research and Development (Birmingham)
British Coal Utilisation Research Association, Monthly Bulletin (London)
British Coke Research Association, Technical Papers (London)
British Dental Journal (London)
British Electrical and Allied Industries Research Association, Reports (London)
British Engineering (London)
British Iron and Steel Federation, Monthly Statistical Bulletin (London)
British Iron and Steel Research Association, Reports (London)
British Journal of Applied Physics (London)
British Steelmaker (London)
Brown-Boveri Review (Baden)
Bulletin of the American Ceramic Society (Columbus, O.)
Bulletin, American Society for Testing Materials (Philadelphia)
Bulletin of the British Scientific Instrument Research Association (London)
Bulletin, British Steel Founders' Association (Sheffield)
Bulletin de Cercle d'Etudes des Métaux (St. Etienne)
Bulletin and Foundry Abstracts of the British Cast Iron Research Association (Birmingham)
Bulletin of the Geological Institute of the Upsala University (Upsala)
Bulletin de l'Institut Polytechnique de Jassy (Jassy, Roumania)
Bulletin of the Institute of Metal Finishing (London)
Bulletin of the Institution of Metallurgists (London)
Bulletin of the Institution of Mining and Metallurgy (London)
Bulletin of Ohio State University Engineering Experiment Station (Columbus, O.)
Bulletin of the School of Mines and Metallurgy, University of Missouri (Minneapolis)
Bulletin des Sociétés Chimiques Belges (Brussels)
Bulletin of the University of Wisconsin, Engineering Experiment Station Series
Bureau of the Census, Facts for Industry

Canadian Journal of Chemistry (Ottawa)
Canadian Journal of Physics (Ottawa)
Canadian Journal of Technology (Ottawa)
Canadian Metals (Toronto)
Canadian Mining Journal (Quebec)
Canadian Mining and Metallurgical Bulletin (Montreal)
Calore (Milan)

Centre de Documentation Sidérurgique, Circulaires d'Informations Techniques (Paris)
Ceramics (Leighton Buzzard)
Chaleur et Industrie (Paris)
Chemical Age (London)
Chemical Engineering (New York)
Chemical and Engineering Mining Review (Melbourne)
Chemical and Engineering News (Washington)
Chemical Engineering Progess (New York)
Chemické Listy (Prague)
Chemisch Weekblad (Amsterdam)
Chemist-Analyst (Phillipsburg, N.J.)
Chemistry and Industry (London)
Chimica e Industria (Milan)
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Ciencia y tecnica de la Soldadura (Madrid)
Circular of the National Bureau of Standards (Washington)
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Claycraft (London)
Coke and Gas (London)
Coke Review (London)
Collection des Travaux Chimiques de Tchecoslovaque (Prague)
Colliery Guardian (London)
Colonial Geology and Mineral Resources (London)
Commonwealth Engineer (Melbourne)
Comptes Rendus de l'Académie Bulgare des Sciences (Sofia)
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Congrès du Groupement pour l'Avancement des Méthodes d'Analyse Spectrographique (Paris)
Corrosion (Houston, Texas)
Costruzioni Metalliche (Milan)
Coventry Engineering Society Journal (Coventry)

Dansk Teknisk Tidsskrift (Copenhagen)
Demag News (Duisburg)
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Discussions of the Faraday Society (London)
Dyna (Barcelona)

E.S.C. News (Sheffield)
Echo des Mines (Paris)
Edgar Allen News (Sheffield)
Edison Electric Institute Bulletin (Philadelphia)
Eidgenossische Materialprüfungs- und Versuchsanstalt für Industrie, Bauwesen und Gewerbe, Berichte (Zürich)
Electrical Engineer and Merchandiser (Melbourne)
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Hutnické Listy (Prague)
Hutnik (Prague)
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Indian Engineering (Calcutta)
Indian Journal of Physics (Calcutta)
Industria y Química (Buenos Aires)
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Instituto de la **Soldadura, Publicacíon** (Madrid)
Instituto Nacional del Carbon Boletin Informativo (Oviedo)
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Instrument Engineer (Luton)
Instrument Practice (London)
Iron Age (New York)
Iron and Coal Trades Review (London)
Iron and Steel (London)
Iron and Steel Engineer (Pittsburgh)
Iron and Steel Institute, Special Reports (London)

Jernindustri (Oslo)
Jernkontorets Annaler (Stockholm)
Journal of the **American Ceramic Society** (Columbus, Ohio)
Journal of the **American Chemical Society** (Washington, D.C.)
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Journal of **Applied Mechanics** (New York)
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Journal of the **British Shipbuilding Research Association** (London)
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Journal of **Chemical Physics** (New York)
Journal of the **Chemical Society** (London)
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Journal of the **Institution of Production Engineers** (London)
Journal of The **Iron and Steel Institute** (London)
Journal of **Mechanical Laboratory** (Tokyo)
Journal of the **Mechanics and Physics of Solids** (London)
Journal of **Metals** (New York)
Journal of the **Optical Society of America** (New York)
Journal of **Petroleum Technology** (Dallas, Texas)
Journal of the **Physical Society of Japan** (Tokyo)
Journal de **Physique et le Radium** (Paris)
Journal of the **Royal Institute of Chemistry** (London)
Journal and **Proceedings of the Royal Society of New South Wales** (Sydney)
Journal and **Record of Transactions of the Junior Institution of Engineers** (London)
Journal of **Research of the National Bureau of Standards** (Washington, D.C.)
Journal of the **Royal Aeronautical Society** (London)
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Journal of **Scientific Instruments** (London)
Journal of **Scientific and Industrial Research** (New Delhi)
Journal of the **Scientific Research Institute** (Tokyo)
Journal of the **Society of Engineers** (London)
Journal of the **Society of Glass Technology** (Sheffield)
Journal of the **South African Institution of Mechanical Engineers** (Johannesburg)
Journal and **Transactions of the Society of Engineers** (London)
Journal of the **West of Scotland Iron and Steel Institute** (London)

Kohászati Lapok (Budapest)
Kungl. Tekniska Hogskolan, Handlingar (Stockholm)
Kyoto University, Engineering Research Institute, Technical Reports (Kyoto)

Laboratoria N.V. Philips' Gloeilampfabrieken, Separaat (Eindhoven)
Lastechniek (The Hague)
Light Metal Age (Chicago)
Light Metals (London)
Lithgow Journal (Glasgow)

Machine Design (Cleveland, Ohio)
Machine Shop Magazine (London)
Machinery (Brighton)
Machinist (London)
Manchester Association of Engineers, Preprints (Manchester)
Maquinas e Metais (Lisbon)
Materials and Methods (New York)
Mechanical Engineering (New York)
Mechanical Handling (London)
Mechanical World (London)
Memoirs of the Faculty of Science, Kyuoyu University (Hukuoka, Japan)
Memoirs of the Faculty of Technology, Tokyo Metropolitan University (Tokyo)
Memoirs of the Geological Survey of India (Calcutta)
Memoirs of the Kyushu University (Hukuoka, Japan)
Mémoires de la Société des Ingénieurs Civils de France (Paris)
Mémorial de l'Artillerie Française (Paris)
Metal Finishing (New York)
Metal Industry (London)
Metal Powder News (New York)
Metal Progress (Cleveland, Ohio)
Metal Treating (New Rochelle, N.Y.)
Metal Treatment and Drop Forging (London)
Metalen (The Hague)
Metall (Berlin)
Metalloberfläche (Munich)
Metallurgia (Manchester)
Metalurgia y Electricidad (Madrid)
Metallurgia Italiana (Milan)
Métallurgie et la Construction Mécanique (Paris)
Metallurgie und Giesserei Technik (Berlin)
Métaux-Corrosion-Industries (Paris)
Metropolitan Vickers Gazette (Manchester)
Michigan University (Ann Arbor)
Engineering Research Bulletins
Engineering Research Circulars
Microtecnic (Lausanne)
Mine and Quarry Engineering (London)
Mineralogical Magazine (London)
Mines Magazine (Denver, Colo.)
Mining, Electrical and Mechanical Engineer (Manchester)
Mining Engineering (New York)
Mining Journal (London)
Mining Magazine (London)
Mitteilungen aus dem Max-Planck-Institut für Eisenforschung (Düsseldorf)
Modern Foundry (Melbourne)
Modern Metals (Chicago)
Müegyetemi Kozlemenyek (Budapest)
Murex Review (Rainham, Essex)

National **College for Heating, Ventilation, Refrigeration and Fan Engineering Bulletin** (London)
National **Physical Laboratory, Reports** (Teddington)
Nature (London)
New Zealand Engineering (Wellington)
New Zealand Journal of Science and Technology (Wellington)
Nickel Bulletin (London)
Non-Destructive Testing (Evanston, Ill.)
Norsk Geologisk Tidsskrift (Oslo)
Nucleonics (New York)

Oil Engine and Gas Turbine (London)
Operational Research Quarterly (London)
Optima (Johannesburg)
Osaka University, Faculty of Engineering Technology Reports (Osaka)
Ossature Métallique (Brussels)
Österreichischer Maschinenmarkt und Elektrowirtschaft (Vienna)
Overseas Engineer (London)

LIST OF PERIODICALS

Peintures, Pigments, Vernis (Paris)
Philippine Geologist (Manila)
Philippine Journal of Science (Manila)
Philips Research Reports (Eindhoven)
Philips Technical Review (Amsterdam)
Philosophical Magazine (London)
Philosophical Transactions of the Royal Society (London)
Physical Review (New York)
Planseeberichte für Pulvermetallurgie (Reutte, Tyrol)
Plating (Jenkintown, Pa.)
Powder Metallurgy Bulletin (Yonkers, N.Y.)
Power and Works Engineer (London)
Post Office Electrical Engineers' Journal (Epsom)
Prace Institutu Metallurgii (Katowice)
Pratique du Soudage (Brussels)
Precision Metal Molding (Cleveland)
Proceedings, American Gas Association (New York)
Proceedings of the American Society for Testing Materials (Philadelphia)
Proceedings of the...Annual Convention of the American Electroplaters' Society (Jenkintown, Pa.)
Proceedings, Australasian Institute of Mining and Metallurgy (Melbourne)
Proceedings of the Australian Institute of Metals (Melbourne)
Proceedings of the Cambridge Philosophical Society (London)
Proceedings, Chemical Engineering Group (London)
Proceedings, Diesel Engine Users' Association (London)
Proceedings of the Durham Philosophical Society (Durham)
Proceedings of the Ebbw Vale Metallurgical Society (Ebbw Vale)
Proceedings of the Indian Academy of Sciences (Bangalore)
Proceedings of the Indiana Academy of Sciences (Greencastle, Ind.)
Proceedings of the Institute of Australian Foundrymen (Melbourne)
Proceedings of the Institute of British Foundrymen (Manchester)
Proceedings of the Institution of Electrical Engineers (London)
Proceedings, Institution of Mechanical Engineers (London)
Proceedings of the Institution of Mechanical Engineers, Automobile Division (London)
Proceedings of the Japan Academy (Tokyo)
Proceedings of the Lincolnshire Iron and Steel Institute (Scunthorpe)
Proceedings, Metal Powder Association (New York)
Proceedings, Natural Gas Department of the American Gas Association (New York)
Proceedings of the Nova Scotian Institute of Science (Halifax)
Proceedings of the Physical Society (London)
Proceedings of the Royal Canadian Institute (Toronto)
Proceedings of the Royal Institution of Great Britain (London)
Proceedings of the Royal Society (London)
Proceedings of the Royal Society of Edinburgh (Edinburgh)
Proceedings of the Society of Antiquaries of Newcastle upon Tyne
Proceedings, Society of Chemical Industry, Victoria (Melbourne)
Proceedings of the Society of Experimental Stress Analysis (Cambridge, Mass.)
Proceedings of the South Wales Institute of Engineers (Cardiff)
Proceedings of the Staffordshire Iron and Steel Institute (Walsall)
Product Engineering (New York)
Product Finishing (London)
Products Finishing (Cincinnati)
Pro-Metal (Berne)
Przeglad Odlewnictwa (Cracow)
Przeglad Techniczny (Warsaw and Lodz)
Publications de l'Association des Ingénieurs de la Faculté Polytechnique de Mons (Mons)
Publications de l'Institut de Recherches de la Sidérurgie (St. Germain-en-Laye)
Purdue University, Engineering Experimental Department (Lafayette, Ind.)
Engineering Extension Series
Engineering Research Series

Quarterly Journal of the Geological, Mining, and Metallurgical Society of India (Calcutta)
Quarterly Journal of the Geological Society (London)
Quarterly Journal of Mechanics and Applied Mathematics (Oxford)
Quarterly Transactions of the Society of Automotive Engineers (New York)
Queensland Government Mining Journal (Brisbane)

Radex Rundschau (Radenthein)
Railway Engineering Abstracts (London)
Railway Gazette (London)
Railway Steel Topics (Sheffield)
Recherche Aéronautique (Paris)
Records of the Geological Survey of India (Calcutta)
Recueil des Travaux Chimiques des Pays-Bas (The Hague)
Refractories Journal (London)
Regional Technical Meetings of the American Iron and Steel Institute (New York)
Reports of the Scientific Research Institute (Tokyo)
Research (London)
Research Association of British Paint, Colour and Varnish Manufacturers' Review (Teddington)
Review of Scientific Instruments (New York)
Reviews of Modern Physics (New York)
Revista de Ciencia Aplicada (Madrid)
Revista di Meccanica (Milan)
Revista de Química Industrial (Rio de Janeiro)
Revue de l'Aluminium (Paris)
Revue de la Faculté des Sciences de l'Istanbul University (Istanbul)
Revue Générale de Mécanique (Paris)
Revue de l'Industrie Minérale (St. Etienne)
Revue de Métallurgie (Paris)
Revue des Produits Chimiques (Paris)
Revue de la Soudure (Lastijdschrift) (Brussels)
Revue Technique Luxembourgeoise (Luxembourg)
Revue Universelle des Mines (Liège)
Rheology Bulletin (New York)
Ricerca Scientifica (Rome)
Rivista di Meccanica (Milan)
Roll'schen Eisenwerke A.G. (Gerlafingen, Switzerland)
Mitteilungen
Werkzeitung
Royal Australian Chemical Institute (Melbourne)
Journal and **Proceedings**
Reviews of **Pure** and **Applied Chemistry**
Rozpravy (Prague)

S.A.E. Journal (New York)
Schweissen und Schneiden (Brunswick)
Schweisstechnik (Vienna)
Schweizer Archiv für Wissenschaft und Technik (Solothurn, Switzerland)
Science (Washington)
Science Abstracts (London)
Science and Engineering (Calcutta)
Science Reports of the Tôhoku University (Sendai, Japan)
Science Reports of the Research Institutes, Tôhoku University (Sendai, Japan)
Scientific Proceedings of the Royal Dublin Society
Sheet Metal Industries (London)
Shipbuilder (Newcastle-on-Tyne)
Silicates Industriels (Brussels)
Société Royal Belge des Ingenieurs et des Industriels (Brussels)
Bulletin Technique
Mémoires
Spectrochimica Acta (Vatican City)
Spectrographic News Letter (Glendale, Calif.)
Stahl und Eisen (Düsseldorf)
Stanki i Instrument (Moscow)
Statens Provningsanstalt (Stockholm)
Berättelse
Meddelande
Steam Engineer (London)
Steel (Cleveland, Ohio)
Steel Processing (Pittsburgh)
Strojirenstvi (Prague)
Structural Engineer (London)
Sudostroyennie (Leningrad)
Sulzer Technical Review (Winterthur)
Sveriges Geologiska Undersökning, Årsbok (Stockholm)
Svetsaren (Gothenburg)
Swansea and District Metallurgical Society, Advance Copies (Gorseinon)

Technik (Berlin)
Technique et Humanisme (Liège)
Technique et Science Aéronautiques (Paris)
Techniques et Civilisations (St. Germain-en-Laye)
Tecnicale Industria (Buenos Aires)
Tecnica Metalúrgica (Barcelona)
Teknisk Tidskrift (Stockholm)
Teknisk Ukeblad (Oslo)
Tidsskrift for Kjemi, Bergvesen og Metallurgi (Oslo)
Times Review of Industry (London)
Tin and its Uses (Greenford)
Tisco Review (Calcutta)
Transactions of the American Foundrymen's Society (Chicago)
Transactions of the American Institute of Electrical Engineers (New York)
Transactions of the American Institute of Mining and Metallurgical Engineers (New York)
Transactions of the American Society of Mechanical Engineers (New York)

Transactions of the American Society for Metals (Cleveland, Ohio)
Transactions of the British Ceramic Society (Stoke-on-Trent)
Transactions of the Canadian Institute of Mining and Metallurgy (Montreal)
Transactions of the Danish Academy of Technical Sciences (Copenhagen)
Transactions of the Faraday Society (London)
Transactions of the Indian Institute of Metals (New Delhi)
Transactions of the Institute of Marine Engineers (London)
Transactions of the Institute of Welding (London)
Transactions of the Institution of Chemical Engineers (London)
Transactions of the Institution of Engineers and Shipbuilders in Scotland (Glasgow)
Transactions, Institution of Gas Engineers (London)
Transactions of the Institution of Mining Engineers (London)
Transactions of the Institution of Mining and Metallurgy (London)
Transactions of the Institution of Naval Architects (London)
Transactions of the Liverpool Engineering Society (Liverpool)
Transactions, Manchester Association of Engineers (Manchester)
Transactions of the Mining, Geological and Metallurgical Institute of India (Calcutta)
Transactions of the Newcomen Society (London)
Transactions of the North East Coast Institution of Engineers and Shipbuilders (Newcastle-on-Tyne)
Transactions of the Royal Canadian Institute (Toronto)
Transactions of the Royal Society of Canada (Ottawa)
Transactions of the Society of Instrument Technology (London)
Transactions of the South African Institute of Electrical Engineers (Johannesburg)

United Effort (Pittsburgh)
United States Bureau of Mines (Washington, D.C.)
Bulletin
Information Circular
Reports of Investigations
Technical Paper
United States Geological Survey, Bulletin (Washington)
Universität für technische Wissenschaften, Fakultät für Berg-, Hütten-, und Forstwesen. Mitteilungen der Berg- und Hüttenmännischen Abteilung (Sopron)
Usco Magazine (Pretoria)
Usine Nouvelle (Paris)

Vacuum (London)
Värmländska Bergsmanneföreningens Annaler (Filipstad, Sweden)
Waseda University, Report of the Casting Research Laboratory (Tokyo)
Welder (Waltham Cross)
Welding Journal (New York)
Welding and Metal Fabrication (London)
Welding Research (London)
Welding Research Council, Welding Research Council Bulletin Series (New York)
Werkstoffe und Korrosion (Mannheim)
Western Metals (Los Angeles)
Wire Industry (London)
Wire Production (London)
Wire and Wire Products (Stamford, Conn.)

Yearbook of the **American Iron and Steel Institute** (New York)
Yearbook of the **Coke Oven Managers' Association** (London)
Yearly Proceedings of the Association of Iron and Steel Engineers (Pittsburgh)

Zeitschrift für Erzbergbau und Metallhüttenwesen (Stuttgart)
Zeitschrift für Metallkunde (Stuttgart)
Zeitschrift des Vereines deutscher Ingenieure (Düsseldorf)

ABSTRACTS

MINERAL RESOURCES

Portuguese Iron Ores. J. M. Cotelo Neiva. (*Inst. Hierro Acero*, 1952 **5,** Apr., 359–365). [In Spanish]. The author describes briefly the sideritic ores of the lower silurian Guadramil deposits, the Moncorvo hematites, the magnetites of Vila Cova do Marao and Alentejo, and the hydrated oxides of Rates.—R. S.

Western Coking Coal Resources. T. G. Ewart. (*Canad. Min. Met. Bull.*, 1952, **45,** May, 264–266). The coal reserves in Canada and the U.S.A. are briefly reviewed, with particular reference to the situation in the West and to coking coals. For the time being, the Crow's Nest area of Alberta and British Columbia can furnish the growing demands for coke both in Western Canada and in the coke-deficient area of the western United States.—T. E. D.

Iron Ore Supply: Present and Future. W. M. Goodwin. (*Canad. Min. Met. Bull.*, 1952, **45,** May, 267–270). Each of the principal iron-ore fields and mines is reviewed briefly, and some specific information concerning them is tabulated. They are the Wabana, Labrador, Sorel, Algoma, Eastern Ontario, Steep Rock, and Pacific Coast deposits. There is a large supply of ore in the East, but comparatively little in the West.—T. E. D.

Conjectural Shape and Extent of the Sydney Coalfield. T. B. Haites. (*Canad. Min. Met. Bull.*, 1952, **45,** May, 292–302). Details are given of the Sydney, Cape Breton Islands, coalfield. Columnar sections of boreholes in a number of localities are shown, and methods of developing the workings are illustrated in plans and sections. (24 references).—T. E. D.

Oil Wells and Iron Mountains. (*Economist*, 1952, **163,** June, 906–908). The development of oil wells and ore fields in Venezuela is described. The development of iron-ore deposits by the Bethlehem Steel Company at El Pao, and by the United States Steel Corp. at Cerro Bolivar on the west of the river is reviewed. The latter deposit consists of a hill containing at least 500 million tons of high-grade ore averaging 63% Fe and virtually free from sulphur.—B. G. B.

Mineral Resources of Madras. M. S. Krishnan. (*Memoirs of the Geological Survey of India*, 1951, **80,** 1–300).

ORES—MINING AND TREATMENT

The Development of Rotary Blast-Hole Drilling in the Jurassic Rocks of Lincolnshire. R. J. M. Dixie and T. M. Dover. (*Trans. Inst. Min. Met.*, 1952–53, **62,** Part I, 23–28).

Iron Ore: Brazil Pecks Away at Vast Blue Lode. (*Iron Age*, 1952, **169,** May 15, 67–69). A description is given of the Caué Peak mine in Brazil. The ore in the region is stated to comprise 25% of the world reserves. Ore now being mined is hematite with 69% iron, and shipments amount to 1½ million tons/annum.—A. M. F.

Vibration Applied to Production. H. E. Hutter. (*Mech. World*, 1952, **131,** June, 255–257). A number of widely differing examples of the use of vibrating equipment for the mechanical feeding of granular material are described.—D. H.

Laws of Crushing in Cylindrical Crushers. T. Seguiti. (*Rev. de l'Ind. Min.*, 1952, **33,** July, 537–546). After a summary of previous work, results of numerous crushing trials carried out on many minerals and rocks are reported. From these, general laws are deduced and a diagram is constructed from which the results of crushing may be predicted.—A. G.

Concentration of Oxide Manganese Ores from the Vicinity of Cleveland, Bannock County, Idaho. K. C. Vincent and D. T. Holmes. (*U.S. Bur. Mines Rep. Invest. No.* 4884, 1952, May). High-grade (38·7%) manganese ore from the Idaho Manganese Mining Co. was found readily amenable to concentration by simple washing and sizing to give a product containing 48·6% Mn. Unsatisfactory results were obtained with other ore-dressing techniques including jigging, heavy-medium separation, and tabling. Medium-grade Hot-Spot ore (26·0% Mn) responded readily to beneficiation by simple washing and gravity methods. Washing followed by removal of −200-mesh material gave a coarse enriched product containing 79·5% of the total manganese and met the minimum 35% marketing specifications without sintering.—B. G. B.

A Sedimentation Balance for Particle Size Analysis in the Sub-Sieve Range. W. Bostock. (*J. Sci. Instruments*, 1952, **29,** July, 209–211). The theory is given of a method for estimating the particle-size distribution of insoluble powder in the sub-sieve range. An apparatus is described in which the

particles are allowed to settle in a suitable liquid on the pan of a torsion balance; the direct deflection on return twist of the torsion wire being used. Results using ground limestone and pyrites are included.—H. D. W.

A Correlation of Solids Turnover in Fluidized Systems. M. Leva and M. Grummer. (*Chem. Eng. Prog.*, 1952, **48,** June, 307–313). The movement of particles in fluidized sand and silica gel beds was studied, and an ' inter-particle ' friction factor is defined. Film coefficients of heat transfer between fluidized beds and the surroundings were shown to increase with the 0·6 power of the particle velocity. Considerable data are presented.—T. E. D.

Sinter Production Tied to Plant Design. M. L. Cover. (*Iron Age*, 1952, **169,** June 5, 145–149). Close control of operations is necessary to produce high-quality sinter. Materials should be 70% or more — 100-mesh and practically all under ¼ in. Constituents should be well mixed and have a carbon content of 4 to 4½% with moisture content between 6 and 10%. Slow air cooling is claimed to give the strongest sinter.—A. M. F.

Enrichment Trials on French Iron Ores Conducted at the Dorr Co. (U.S.A.). (*IRSID Publication*, 1952, Series A, No. 24, May). The report describes laboratory tests on the magnetizing roasting of many French ores, and pilot-plant trials on the roasting and magnetic concentration of Mont St. Martin ore. For this ore a concentrate with 50% iron and a recovery of 90% was attained. At 800° C. the ore could be completely reduced under fluidizing conditions.—A. G.

FUEL—PREPARATION, PROPERTIES, AND USES

Coal Structure and X-Ray Scattering. (*Brit. Coal Utilisation Res. Assoc., Quarterly Gaz.*, 1952, No. 15, 14–18). Coal is a closely packed assemblage of approximately identical spheres, or ' micelles.' To study this structure, X-ray scattering methods have been used, but in this case it is the low-angle scattered rays which are important. A new camera is described which must work in a vacuum because air scatters the long-wavelength X-rays which are used. The results from the study of nine well-characterized vitrinites are discussed.—J. C. B.

Evolution and Combustion of Volatile Matter from Coals. Part I—Thermal Decomposition of Organic Substances. P. H. Given. (*Brit. Coal Utilisation Res. Assoc. Monthly Bull.*, 1952, **16,** June, 247–257). The course of thermal decomposition of pure compounds under the mildest conditions can be predicted with some confidence and examples are given.

Evolution and Combustion of Volatile Matter from Coals. Part II—Thermal Decomposition of Coals. A. H. Billington, I. G. C. Dryden, and D. H. Napier. (*Brit. Coal Utilisation Res. Assoc. Monthly Bull.*, 1952, **16,** June, 258–270). It is considered likely that the decomposition of bituminous coals results in the formation of rather small reactive fragments, these initial products rapidly interacting to form compounds of high molecular weight, and gases. At higher temperatures these complex compounds are themselves broken down, but in more gradual stages ; this is followed by a further building up to form the tar constituents known as ' free carbon.' (114 references).—B. G. B.

Evolution and Combustion of Volatile Matter from Coals. Part III—Combustion and Related Factors. J. R. Arthur and D. H. Napier. (*Brit. Coal Utilisation Res. Assoc. Monthly Bull.*, 1952, **16,** July 309–319). Extremely little work has been published concerning the combustibility of volatile matter. This is because of inadequate means of describing volatile matter and of the practical difficulties in studying it. The effect of fuel-bed conditions on its mode of release and the combustion of some of the simpler constituents likely to be present are discussed.—B. G. B.

Emergency Fuels. W. Trinks. (*Indust. Heating*, 1952, **19,** June, 1058–1060). A review is made of investigations into the uses of producer gas. Moderate enrichment of the blower air with oxygen increases the flame temperature, but the enriched air must contain more than 50% oxygen if the high-grade producer gas is to replace rich fuels without major changes in burner and furnace design.—B. G. B.

Industrial Gas Nomenclature. D. A. Campbell. (*Indust. Heating*, 1952, **19,** June, 1020–1024). The purpose of the article is to standardize the names of gas-combustion systems, mixers, and burners. The proposals are issued by a committee of the American Gas Association.—B. G. B.

Methane and Coal. Sir Alfred Egerton. (*Nature*, 1952, **170,** July 19, 93–97 : *B.C.U.R.A. Quarterly Rev.*, 1952, No. 16, 10–13 ; *Engineering*, 1952, **173,** May 30, 678–679 ; *Fuel*, 1952, **31,** Oct., 385–402). The origin of methane found trapped in coal is discussed. A method of utilization of the firedamp energy in mine ventilation air in which, after suitable pre-heating, the gas operates a turbine, is proposed. Results on the combustion of weak methane–air mixtures are given and the possible use of methane in the internal combustion engine is considered.—A. G.

Efficient Furnace Control by Direct Visual Observation. F. Smith. (*Mech. World*, 1952, **132,** July, 34–36). The three basic factors in furnace observation, namely, air/fuel ratio, optimum rate of fuel consumption for a given furnace, and furnace pressure are discussed.—D. H.

Metal Temperature in Regenerative and Recuperative Air Preheaters. T. A. Widell and S. I. Juhasz. (*Acta Polytechn.*, 1952, 103, *Mechanical Engineering Series*, **2**, No. 6). Flue-gas condensation on the metal surface generally causes air preheater troubles. These can be avoided by increasing the metal temperature. The surface temperature of the cold end of the preheater is increased by by-passing cold air or the flue gas, hot-air recirculation, decreasing the air-preheater surface, or by changing counterflow to parallel flow. A new method is suggested for regenerative air preheaters : A combination of counterflow and parallel flow called ' combiflow.'

The Utilization of Coal. E. A. C. Chamberlain. (*Trans. Inst. Min. Eng.*, 1952, **3,** June, 565–582 ; *Trans. Mining Inst. of Scotland*, 1951–52, **65,** Part 3, 176–197). It is stated that 15 million tons of coal/annum could be saved by the more efficient use of existing fuel-burning equipment. The use of pulverized fuel with large unit boilers for power generation may assist washing practice by eliminating the problem of washing fines. The development of the iron and steel industry will require coking coal to be reserved for the production of metallurgical coke while the gas industry makes use of non-coking coal.—B. G. B.

Coal Preparation Plant of Old Sydney Collieries, Limited, Sydney Mines, C.B. J. A. Russell. (*Canad. Min. Met. Bull.*, 1952, **45,** June, 327–330). The new plant, designed for handling 325 tons/hr. of raw coal, was installed to cope with the increased quantity of dirty coal encountered because of the programme of mechanization in the mines. A McNally Norton washer is used. Diagrams of the plant and the flow sheet are given.—T. E. D.

Progress of Coal Technology: Coal Preparation. E. Swartzman. (*Canad. Min. Met. Bull.*, 1952, **45,** June, 347–357). A survey of modern developments in heavy-medium coal washing mentions the characteristics of several different methods. Recent modifications to the Baum jig wet washer are described. Comparisons of hand picking and mechanical cleaning are given. The separation of fines by heavy-media and by froth flotation is surveyed, and dust reduction, drying, and dewatering are outlined. The 7-group standard size classification for graded coal is given. Carburized briquette production is mentioned. (24 references).—T. E. D.

Modern Coal Processing Equipment at New Plant Achieves Uniform Quality. (*Indust. Heating*, 1952, **19,** Apr., 640–650). The new plant for washing, cleaning, and grading coal has an output of 1275 tons/hr. The raw coal is screened and then processed either by vibrating tables, sand flotation, or McNally Baum jigs, in order of increasing coal size. Removal of moisture is carried out by one or a combination of the following devices : Drainage dewatering screens, settling tanks, centrifugal dryers, thermal flash dryers, and thermal conveyor dryers. Facilities to avoid stream and air pollution are also described.—B. G. B.

Commercial Pulverising Experience—Report Based on Replies to a Questionnaire. (*Brit. Elect. Allied Ind. Res. Assoc.*, 1947, *Technical Report* P/T 105). Industrial pulverizers are invariably airswept and the majority operate on a closed circuit. High-speed mills account for only a small proportion of the total output. No connection could be established between the mill power and coal type or the conditions of operation of the pulverizer ; variation in fan power did, however, affect the operation of the pulverizer.—B. G. B.

Swelling Pressures in the Coke Oven. (*Coke Gas*, 1952, **14,** Aug., 280–284, 288). A moving-wall test oven, erected by the British Coke Research Assoc. at Pontypridd, is described. Results of tests to determine swelling pressures are given, and the influence of bulk density of charge is shown. The rate of

heating, and blending were also investigated. The measurement of the pressure generated within the charge was made by a specially designed probe which is described in detail. A theory for the origin of coking pressure is suggested.—T. E. D.

Shutting Down Coke Oven Batteries. C. A. Covington and A. H. Parthum. (*Amer. Iron Steel Inst. Regional Tech. Meetings*, 1950, 25–27). See "Shutting Down Coke Oven Batteries, Campbell Coke Plant" (*J. Iron Steel Inst.*, 1951, **169,** Dec., 396).

The Effect of the Twin Collecting Main on Coke Ovens on the Yield of By-Products. W. Brösse, E. Comblés, and J. Tegethoff. (*Technische Mitteilungen Krupp, Forschungsberichte*, 1943, **6,** Feb., No. 2, 20–30). An experiment using a battery of 25 ovens and a twin collecting main is described in which the effect of different switching of the collecting mains on the yield of the coal by-products was observed. The effect of using (*a*) one collecting main, (*b*) both mains as exhaust mains, (*c*) the Otto connection, and (*d*) the Concordia-Nettlebusch connection is described, the working time being maintained at 18 hr. Temperatures were measured throughout the course of the experiments and the yield of ammonia, phenol, tars, benzols, and other tar oils recorded, together with their compositions, for each process.—R. J. W.

Metallurgical Coke. (*Chem. Age*, 1952, **67,** Aug. 16, 229–231). The coking of heavy oils in the United States is mentioned. The method of production of petroleum coke is outlined, and the properties of the product are listed. A comparison is made of the continuous contact and delayed coking methods, with particular reference to the characteristics of the products.—T. E. D.

New Method of Producing Metallurgical Coke from Lothringian Coals. C. Abramski. (*Glückauf*, 1952, **88,** July, 694–698). Two methods, in use in France and Germany, for utilizing low-quality Lorraine coals, in conjunction with good coking coals in the ratio of 3/2 are described.—P. F.

On the Electrical Coking of Coals. E. Blümel. (*Glückauf*, 1940, **76,** Apr. 13, 337–341). An earlier publication of an American furnace for coking electrically is criticized. Within the plastic zone, the gases formed cannot reach the furnace wall radially, and must rise through the annealing coke and undergo decomposition, as can be followed by gas analysis. The effect of frequent changes in temperature, of the importance of refuse and coking speed, and of the expansion pressure has not been clarified. The electrical method is not so economical as gas-heated furnaces.—R. J. W.

Low Temperature Carbonization of Coal A. Lahiri. (*J. Sci. Indust. Res.*, 1952, **11,** Apr., 146–158). In India this process would be important for the production of semi-coke. The various products and types of plant are reviewed, and it is concluded that the Lurgi low-temperature system may be particularly suitable.—E. T. L.

Technique of the Use of X-rays in the Study of Coke Making. A.-A. Peytavy and J. Lahouste. (*Compt. Rend.*, 1952, **234,** Feb. 25, 934–935). X-ray examination of a mass of coal during coking makes possible precise measurements of the deformations and of the thickness and speed of displacement of the plastic layer.—A. G.

Laboratory Methods for Determining the Probable Strength of Coke. H. R. Asbach and W. Brösse. (*Technische Mitteilungen Krupp, Forschungsberichte*, 1943, **6,** Feb., No. 2, 30–37). A method for determining the probable strength of coke, developed from Roga's drum method is described. An automatic expansion pressure apparatus (by Asbach) was used to break up a coke mass in a cylinder rotating for 2500 revolutions at 40 r.p.m. The remaining portion of the coke over 1 mm. yielded the so-called 'Hanover number,' which is closely connected with the works barrel strength.—R. J. W.

The Physical Testing of Low-Temperature and High-Temperature Coke in a 5-kg. Drum. E. Comblés and W. Surmund. (*Technische Mitteilungen Krupp, Forschungsberichte*, 1943, **6,** Feb., No. 2, 38–42). A 5-kg. drum was developed to investigate the physical conditions under which low-temperature coke (40–90-mm. granulation) could be used as a water-gas generator.—R. J. W.

The Smoothing Effect of Hold-Up and Mixing in Gasholders. P. V. Danckwerts and E. S. Sellers. (*Coke Gas*, 1952, **14,** July, 247–251). A useful function of a gasholder is to smooth out variations in calorific value between inlet and outlet; the factors involved are explained, and methods of calculating smoothing effects are described.—T. E. D.

TEMPERATURE MEASUREMENT AND CONTROL

A Recording Device for Surface Temperature Measurements. N. Sasaki and A. Kamada. (*Rev. Sci. Instruments*, 1952, **23,** June, 261–263). A method is described for periodical heating of the measuring junction of a thermocouple. Movements of a spot of light from a galvanometer in the circuit are recorded on photographic film. The designs of a two-junction thermocouple and a portable thermostat are given.—H. D. W.

A Visual and a Photoelectric Portable Colour Temperature Meter. H. G. W. Harding. (*J. Sci. Instruments*, 1952, **29,** May, 145–148). The construction and calibration of the two-colour temperature meter are described. The range of the visual meter is from 2000° K. to infinite temperature, and that of the photoelectric meter from 1800° to 10,000° K. The accuracy of both instruments is estimated to be about 100° at 3000° K. and 1000° at 10,000° K.—H. D. W.

A Brightness Temperature Pyrometer Using a Photoconductive Cell. E. C. Pyatt. (*J. Sci. Instruments*, 1952, **29,** Apr., 125–127). An instrument is described using a type M2 lead sulphide photoconductive cell as the balance detector in a low-temperature pyrometer. Details of the cell, optical system, and mill detector circuit are given. Temperature ranges of 100–175° C., 150–220° C., 210–330° C., and 300–500° C. are available, the accuracy being ± 5° C. for a single reading.

Electronic Temperature Control. (*Metal Ind.*, 1952, **81,** Aug. 1, 91–93). A controller developed by Kelvin and Hughes Ltd., London, is described, and several industrial applications and installations are discussed and illustrated.

Lead Sulphide Photo-Cells. C. J. Milner and B. N. Watts. (*Research*, 1952, **5,** June, 267–273). Lead sulphide cells are characterized by their fast response and high sensitivity. Apart from methods of production, mechanism of photosensitivity, and properties of these cells, their applications are described. Included in these is pyrometry where the range of a photocell pyrometer has been increased to include temperatures as low as 100° C. In absorption spectrometry the resolution available has been improved to make possible the study of infra-red atomic emission spectra of much longer wavelength.—J. C. B.

Interpretation of the Energy Density of a Black Body and a Proposed Temperature Scale. Y. Rocard. (*Compt. Rend.*, 1952, **234,** June 16, 2427–2428). From the equation giving the energy density $U = \frac{8}{3}kT(\beta T)^3$ (where k is the Boltzmann constant), a new unit of temperature is derived conforming to the Kelvin scale. On this new scale, room temperature is 1000° R.N.—A. G.

Programme Control of Gas-fired Industrial Furnaces. L. Walter. (*Indust. Gas*, 1952, **15,** Mar., 172–178). Brief details are given of certain time–temperature controllers used in the steel and ceramic industries.—D. H.

The Choice of Thermostats for Gas-Heated Vessels. L. Walter. (*Indust. Gas*, 1952, **15,** Apr., 204–210). A short description is given of each type of thermostat or gas regulator for temperature control. The advantages and particular usages of each are mentioned.—D. H.

Temperature Regulation of Metallurgical Furnaces of all Types. C. Sieber. (*Metallwirtschaft*, 1941, **20,** June, 603–610). Various types and methods of controlling gas-fired and electrical furnaces are described.—K. G.

REFRACTORY MATERIALS

The Landore Silica Brickworks of Richard Thomas and Baldwins Ltd. (*Claycraft*, 1952, July, 544–546). In 1948 the redesign of the entire plant was commenced but it was not until 1950 that the now obsolete 'wet' process was replaced by the present 'dry' method. In 1950 a tunnel kiln for firing silica bricks, designed by Gibbons Bros. Ltd., Dudley, was installed.—E. C. S.

An X-Ray Study of the Crystalline Phases that Occur in Fired Clays. H. M. Richardson and F. G. Wilde. (*Trans. Brit. Ceram. Soc.*, 1952, **51,** July, 387–400). The chemical analysis and the crystalline impurities of seven clays were first determined. The crystalline phases formed during firing these clays to temperatures between 800° and 1350° C. were then identified by X-ray diffraction. It was concluded that an X-ray powder photograph of a fireclay can be used to give some evidence of the heat-treatment the clay has received.

The Firing Expansions of Certain Chrome–Magnesite Products. G. H. B. Lovell. (*Trans. Brit. Ceram. Soc.*, 1952, **51,** July, 369–386). By firing mixtures of MgO with the spinels associated, with chrome ores with the sesquioxides Al_2O_3,

Cr_2O_3, and Fe_2O_3, and with various sesquioxide solid solutions, it has been shown that permanent expansions occur only when free sesquioxide or sesquioxide solid solutions are present. These expansions are attributed to recrystallization, resulting in an increase in porosity. Experiments confirm that the firing expansions of certain chrome–magnesite products are due to the magnesite reacting with free R_2O_3, either present in the raw materials or resulting from the oxidation of the chrome grains. The main factors controlling expansion are the rate at which the chrome ore oxidizes and the percentage of MgO already present in the chrome grains. Additions of serpentine slightly diminished the expansion.

The Decomposition of Kaolinite by Heat. E. B. Colegrave and G. R. Rigby. (*Trans. Brit. Ceram. Soc.*, 1952, **51,** June, 355–367). The nature of the dehydration of kaolin and the mechanism of mullite formation on the firing of kaolin has been investigated by differential thermal analysis and X-ray diffraction. The exothermic reaction which occurs at about 960–1000° C. is the sudden crystallization of γ-Al_2O_3 from the amorphous phase which is prevented at lower temperatures by the SiO_2 in intimate contact with it. Formation of γ-Al_2O_3 appears to be an essential precursor of mullite. The form of the SiO_2 residue, after perchloric acid treatment of the dehydrated kaolin, shows that the Al_2O_3 and SiO_2 are not in chemical combination.—E. C. S.

The System Al_2O_3–TiO_2–SiO_2. Y. M. Agamawi and J. White. (*Trans. Brit. Ceram. Soc.*, 1952, **51,** May, 293–325). Some 45 mixtures were prepared and the equilibrium phases identified by quenching, followed by microscopical and X-ray examinations. From the results, the equilibrium diagram of the SiO_2–TiO_2–Al_2O_3 system was constructed. The primary fields of mullite, cristobalite, and TiO_2–Al_2O_3 meet at a reaction point having the composition 79·4% SiO_2, 8·2% Al_2O_3, 12·4% TiO_2 at 1480° C.; and a ternary eutectic, where cristobalite, rutile, TiO_2–Al_2O_3, and liquid coexist, occurs at 79% SiO_2 7·5% Al_2O_3, 13·5% TiO_2 at 1470° C. Bunting's placing of the binary SiO_2–TiO_2 eutectic at 10·5% TiO_2 was confirmed. In compositions containing 98% SiO_2, least liquid occurs in that in which TiO_2 and Al_2O_3 are in the ratio to give TiO_2–Al_2O_3.—E. C. S.

On the Thermal Decomposition of Dolomite. IV—Thermogravimetric Investigation of the Dolomite Decomposition. R. A. W. Haul and J. Markus. (*J. Appl. Chem.*, 1952, **2,** June, 298–306). The thermal decomposition of dolomite at various constant temperatures and CO_2 pressures was investigated by the loss-of-weight method. Depending on these conditions dolomite can be decomposed either stepwise to MgO and $CaCO_3$ (' half-burnt dolomite ') with subsequent dissociation of the $CaCO_3$ or in a single stage straight to MgO and CaO. A reaction mechanism is suggested on the basis of these thermogravimetric results in conjunction with thermodynamic calculations and X-ray studies.—E. C. S.

An Improved Apparatus for the Differential Thermal Analysis of Minerals. J. J. Theron. (*Brit. J. App. Phys.*, 1952, **3,** July, 216–220). Apparatus used by other authors is briefly discussed. The design of new equipment suitable for the differential thermal analysis of clays is given together with details of the proportioning temperature control, and circuits of the programme control and D.C. amplifiers.

The Role of the Alumina Content in Refractory Products. L. Halm. (*Silicates Indust.*, 1952, **17,** Mar., 77–88). A critical review of the properties of a number of ternary systems, all containing silica and alumina is given, with special reference to the influence of the alumina content in silica bricks. The effect of impurities on their refractory properties is discussed, and the Continental attitude of emphasizing the physical state of bricks in assessing their quality is contrasted with the tendency in America to rely primarily on the chemical analysis of the material. The correct basis for assessing brick quality is shown to lie between these two methods.—P. F.

Contribution to the Investigation of the Cr_2O_3–FeO–SiO_2 System. R. Zoja. (*Met. Ital.*, 1952, **44,** July, 247–249). [In Italian]. The difficulties encountered in the study of the Cr_2O_3–FeO–SiO_2 system are discussed and methods of overcoming them are described. The method adopted has enabled the approximate position of the three binary eutectics to be determined.—M. D. J. B.

Kinetics of the Dissolution of Corundum in Binary Silicate Slags. N. McCallum and L. R. Barrett. (*Silicates Indust.*, 1952, **17,** Mar., 89–90). [In English]. Data are presented on the rates and energies of activation of corrosion of single crystals of corundum and spinel ($MgO.Al_2O_3$) by synthetic calcium, sodium, and magnesium silicate slags. Further, several determinations of the rates of interdiffusion of liquid lime–alumina–silica slags were made. From these and from the corrosion experiments, both processes were found to take place at rates increasing with temperature according to the Boltzmann law. It is postulated that the rate-determining process in the corrosion of single crystals is a reaction at the crystal surface.—P. F.

Rammed Open-Hearth Bottoms Increase Production. C. Heilig. (*Iron Age*, 1952, **169,** June 5, 133–137). The method of construction of rammed hearths for the 250-ton furnaces at Jones and Laughlin Steel Corp. is described. The mix is laid in 3- to 4-in. layers and rammed with air-driven tampers. Complete laying and burning-in averaged five days. A. M. F.

Refractory Concrete in Gasworks and Coke-Oven Plant. T. D. Robson. (*Coke Gas*, 1952, **14,** July, 241–246). Refractory concrete consists essentially of a heat-resistant aggregate and a hydraulic cement of the high-alumina type. With crushed aluminous firebrick as aggregate, the concrete can be used at temperatures up to 1300° C., while with special aggregates, temperatures of up to 1400–1600° C. can be reached. The technical factors involved in the applications of refractory concrete are outlined, and examples of its use in coke ovens and gasworks are given.—T. E. D.

Some Experiences in the Use of Chrome–Magnesite Refractories. G. R. Bashforth. (*Metallurgia*, 1952, **45,** Jan., 12–16). The use of chrome–magnesite refractories is related to the structure and constitution of the materials. Microscopical examination was made of various types of brick used in a trial. The durability depends on control of the chrome/magnesite ratio, composition of the gangue, and respective grading of the chrome and magnesite fractions.—B. G. B.

Calculations on Carbon Hearths for Blast Furnaces. E. W. Voice. (*Iron Steel Eng.*, 1952, **29,** July, 125–128). The author discusses the optimum type of carbon, thickness of construction, and type and size of carbon block. Reference is made to theoretical and practical work carried out by B.I.S.R.A. Methods of determining thermal control of the hearth bottom are examined. The possibilities of air cooling immediately below the carbon are considered, and a vertical hexagonal block with corrugate sides is suggested. Model experiments are described.—M. D. J. B.

Fundamental Considerations Regarding the Use of Basic Refractories in Metallurgy. L. Hütter. (*Osterr. Masch. Elektrowirtschaft*, 1952, **7,** Jan., 15–21). The advantages of basic refractories over silica for basic open-hearth furnace roofs are pointed out, and the development of suitable magnesite and chrome–magnesite bricks for this purpose is discussed. Correct design of the furnace is important as well as the choice of the most suitable material. Special basic refractories are practicable for this purpose.—H. R. M.

BLAST-FURNACE PRACTICE AND PRODUCTION OF PIG IRON

Model Experiments to Develop New Designs of Waste-Gas Pipe Bends with Reduced Pressure Losses for Blast Furnace Stoves. W, Barth, H. Kredel, and E. Laforsch. (*Stahl u. Eisen*, 1952, **72,** May 22, 617–620). The pressure drop in the waste-gas mains of blast-furnace stoves has been determined by experiments on models. These showed that present conventional designs are aerodynamically unsound and can be much improved by the use of new shapes of bends. While retaining the existing damper and junction cross-sections, a reduction of pressure drop to one-third to one-fifth of previous values was obtained. The investigations indicated that, with the recommended design, even sharp bends can be introduced with small pressure loss.—J. P.

Flow Patterns in Hot-Blast Stoves from Tests on Models. M. Hansen. (*Arch. Eisenhüttenwesen*, 1952, **23,** July–Aug., 245–252). Two model blast stoves have been constructed with round and oval combustion chambers, respectively. The checkerwork was simulated by a packing of hexagonal tubes. The ends of these tubes could be restricted by placing across the end of the model stove a throttling plate, pierced to correspond with each tube. Three throttling plates were employed so as to produce low, medium, and high pressure loss in the system. A pitot tube was used to measure gas velocity

at the exit of each tube. The hoods of the stoves could be fixed close to or distant from the checkerwork so as to simulate a low or a high hood. Across the centre-line of the hood were drilled 25 test positions to measure static pressure and local convective heat transfer. The principle conclusions were : The oval combustion chamber is clearly superior to the round. The gas reversal, and particularly the heat convection in the hood, are more uniform and therefore more favourable. Rebounding from the hood is smaller. As far as heat convection and gas distribution through a modern design of checkerwork is concerned, there is little difference between a low and a high hood. With a low hood, however, the undesirable heat loss by radiation amounts to only 50–60% and that by radiation and convection together to 60–70% of those with a high hood. Moreover, for a given size of stove casing, a larger checkerwork can be installed. These advantages favour the low hood. The tests have shown the importance of resistance to flow in the checkerwork in obtaining a uniform gas distribution. The pressure drop through a modern filling with narrow channels is such that some degree of uniformity of gas distribution is to be expected. Some of the improvement in the performance of heating stoves built during the last ten years can be attributed to a more uniform gas distribution as a result of the increased resistance to flow in the checkerwork. The flow model is a valuable and inexpensive tool for obtaining information about processes occurring inside heating equipment, provided that gas flow plays a deciding part.—J. P.

Report on the Work of the Hot-Blast Stove Committee. W. Feldmann. (*Stahl u. Eisen*, 1952, **72,** July 31, 928–933). This sub-committee of the Blast Furnace Committee of the Verein Deutscher Eisenhüttenleute has, during the past ten years, examined the rôles played by the various components in determining the overall efficiency and life of blast-heating stoves. Attention has been paid to the burner, combustion chamber, hood, checkerwork, and insulation. It is proposed that all newly erected stoves be the subject of tests to be carried out by the blast-furnace management and the fuel department of the individual firms under guidance from the Wärmestelle, Düsseldorf. The tests and methods to be employed are described in an appendix by M. Hansen.—J. P.

New Look Blast Furnaces ? (*Steel News*, 1952, **3,** Aug., 6–7). The possible development of low-shaft furnaces for the smelting of iron from low-grade raw materials is suggested. Some work that has already been done is briefly outlined.

Recent Experiences with the Smelting of Iron Ores in the Low-Shaft Furnace. E. Killing. (*Stahl u. Eisen*, 1952, **72,** July 31, 925–928). The results are given of a year's trials with a Humboldt low-shaft furnace. Originally the carbonization and smelting stages were separate but later both operations were performed in the one furnace. Briquettes of non-coking coal mixed with ore fines produced a hot, low-sulphur foundry iron, sometimes very low in carbon. Lean and rich ores were smelted with various types of coal. The economics and, particularly, the possibility of being independent of imported raw materials are discussed.—J. P.

The Use of Sintered Pyrrhotite Residues in the Production of Low Phosphorus Pig Iron. L. A. Miller. (*Amer. Iron Steel Inst. Regional Tech. Meetings*, 1950, 91–105). The author describes the design and operation of the blast-furnace at Lyles-Wrigley, Tennessee, which produces low-phosphorus pig iron from a burden consisting mainly of sintered pyrrhotite residues. The advantages and disadvantages of using this material are discussed, and the differences between this and normal blast-furnace practice are outlined.—G. F.

High Top Pressure: Further Operating Experience with Clyde No. 2 Furnace. R. P. Towndrow and W. Banks. (*West of Scotland Iron and Steel Inst.*: *Iron Steel*, 1952, **25,** June, 291–296). After describing the layout and normal operation of the blast-furnace plant at the Clyde Iron Works, the authors compare the results obtained in two periods in which the furnaces were driven for maximum production. In the first period, normal top pressure was used, and in the second, one furnace was worked with high top pressure. The latter procedure enables more wind to be blown and more coke to be burnt with a slight relative coke economy, with the added advantage that it permits harder driving without excessive flue-dust production and irregular stock movement.—G. F.

Influence of the Mass and Nature of Blast-Furnace Slag on Pig-Iron: Suggestion of Occurrence of an "Inertness Temperature" of Slag. J. G. Platon. (*Iron Coal Trades Rev.*, 1952, **165,** Aug. 8, 311–312). The author discusses the action of slag in the blast-furnace and the effect of the slag temperature, composition, and mass on the pig iron produced. A new conception of an 'inertness temperature' of slag in contact with coke in the furnace is put forward ; this factor controls the composition and temperature of the iron.—G. F.

Desulphurization of Pig-iron with Solid Lime: Use of Lime-Coated Coke. H. L. Saunders, V. Giedroyc, and T. E. Dancy. (*Iron Coal Trades Rev.*, 1952, **165,** Aug. 1, 261–264). After briefly surveying methods of desulphurizing pig iron with solid lime, the authors propose a method which involves the use of lime-coated coke. It is suggested that, by combining this process with partial desiliconization with oxygen, heat losses would be compensated and metallurgical load on the open-hearth furnace would be substantially lowered.—G. F.

Tests with Oxygen-Enriched Blast on Rich and Lean Ore Burdens. W. Lennings. (*Mitteilungen aus den Forschungsanstalten des Gutehoffnungshütte-Konzerns*, 1943, **10,** Dec., No. 5, 81–93). Using an experimental blast-furnace, a series of experiments with lean ore, 50% iron constituent, and very high iron burdens, was carried out. Enriching the blast with oxygen gave a large increase in production, and also, when certain preliminary conditions were observed, a considerable saving of coke. Relationships between the weight of burden, amount of slag, coke consumption, coke throughput and production of pig iron were observed.—R. J. W.

Fragmentation of Ores. J. Debatty. (*Mém. Centre National Recherche Mét.*, 1952, May, 15–22). A survey is made of work on fragmentation under test conditions and in the blast-furnace, and the mechanism of the breakdown of ore lumps is discussed.—T. E. D.

The Effect of Blast-Furnace Operation on the Course of Reactions in Basic-Bessemer Steel Melts. W. Oelsen and E., Eickworth. (*Stahl u. Eisen*, 1952, **72,** May 22, 597–605). The results of works' trials have shown that the reactivity of carbon in blast-furnace metal during blowing in the basic-Bessemer converter can vary greatly. This showed itself by differences in reduction of manganous and ferrous oxides during carbon removal. Nitrogen pick-up during carbon removal was lower in those melts having more reactive carbon and these melts were also more easily blown than those with less reactive carbon. The iron with the less reactive carbon came from blast-furnaces with high output rates. This shows that blast-furnace operation effects the subsequent converter reactions.—J. P.

Modifying the Driving of a Blast-Furnace by Varying the Slag Composition. W. Wolf. (*Stahl u. Eisen*, 1952, **72,** June 19, 777–778). Earlier investigations suggested that scaffolding in the blast-furnace was likely to occur with highly basic working. This is now confirmed. A blast-furnace which was operating at a $CaO : SiO_2$ ratio of 1·2 and driving at the walls showed, at very high coke consumption, high blast pressure and high waste-gas temperature and a large amount of flue dust, and it was not possible to attain the rated output of the furnace. All efforts to correct operating conditions, were unsuccessful until the $CaO : SiO_2$ ratio was lowered to 0·8 by reducing the amount of limestone added to the burden. Almost immediately the driving became uniform, the coke rate was reduced from 1150 to 950 kg. per ton, the blast pressure and waste-gas temperature and amount of flue dust fell and the desired output of 600 tons per day was attained.—J. P.

Blast Furnace Instrumentation, J. D. May. (*Instrument Engineer*, 1952, Oct., 32–38 : *Iron Coal Trades Rev.*, 1952, **165,** Oct. 31, 951–957). The paper describes the application of instruments to blast-furnace installations and the benefits these instruments provide to plant operators.—J. C. B.

Instrumentation at Modern Ironmaking Plants—I. D. W. Gillings. (*Instrument Practice*, 1952, **6,** July, 604–615). A general description is given of the layout and processes of a blast-furnace plant. The instruments required for the daily operation of the furnace are described, together with those used for experimental purposes, such as stack-gas sampling, stockline profile recording, and measuring the rate of refractory wear.—H. D. W.

TREATMENT AND USE OF SLAG

Process for Granulating and Supercooling Liquid Basic-Bessemer Slags with Compressed Air. W. Köhler. (*Stahl u. Eisen*, 1952, **72,** June 19, 779). A process is described for the production of dust-free, free-flowing basic slag fertilizer in which the liquid slag is granulated by compressed air and

sprayed with water. The high solubility resulting from the supercooled state renders grinding unnecessary and the fertilizer can be spread in the granulated state. Field and laboratory tests have shown it to be the equal of finely ground slag.—J. P.

PRODUCTION OF STEEL

Report on the Swedish Tour from the 11th to the 16th of September, 1951. (*IRSID Publication*, 1952, Series B, No. 14, Mar.). Part one contains a general account of Swedish metallurgy with descriptions of the Domnarvet, Surahammar, and Aresta works and the Metallographic Institute, Stockholm. The second part deals with the following special aspects : (*a*) Desulphurization of iron by the Kalling process ; (*b*) electromagnetic stirring in the arc furnace ; and (*c*) high-frequency furnace practice in Sweden.—A. G.

A Usconian Helped to Build the Turkish State Steelworks. R. Curnick. (*Usco Mag.*, 1952, **3**, June, 6–8). A short description of the building of the Karabuk steelworks in Turkey is given.—B. G. B.

Estimation of the End of the Carbon Blow, and of Certain Earlier Points in the Basic-Bessemer Process. K. G. Speith and H. Bücken. (*Stahl u. Eisen*, 1952, **72**, July 31, 934–935). In the production of low-nitrogen steels, the time at which additions of solid oxidizing and cooling agents are made is of great importance, yet the correct moment cannot be decided by simple timing. The amount of oxygen or air blown through the metal is, however, a reliable guide. A nomogram is presented from which times previous to the end of the carbon blow may be estimated for charges of various weights and blowing rates. The nomogram refers to one type of hot metal blown with air, but instructions are given for its modification to suit different irons and various degrees of oxygen enrichment.—J. P.

The Production of Steel by Converting with High Purity Oxygen. O. Cuscoleca, K. Rösner, and W. Kühnelt. (*Mitt. Oesterreichisch-Alpine Montangesellschaft*, 1952, Jan., 1–29). [In German and English]. Details of the development of the operation of converters in Austria, using a pure oxygen blast, are described with particulars of the plant and practice. After charging the converter with scrap, hot metal, lime, and flux, the oxygen jet is introduced through the throat of the converter and the oxygen is turned on. In the course of the refining process lime and scrap are added through chutes for slag and temperature control ; details of the metallurgical reactions occurring are given. Rimming steels made by this process are of high purity and have little tendency to segregation and can be used to manufacture any rolled or forged products that are usually made from rimming steel. Owing to its low age hardenability the steel is also very suitable for cold drawing, cold rolling, or deep drawing. High-grade killed steels are also produced and the properties of low-carbon steel plate, heat-treatable steels, case-hardening steels, and rail steel are given.—B. G. B.

Refining of Steel with Pure Oxygen. F. Grohs. (*Österr. Masch. Elektrowirtschaft*, 1952, **7**, Jan., 12–13). Iron produced from Austrian ore is normally too low in silicon and phosphorus for making steel in a converter. A method of producing steel by blowing a converter with oxygen has been developed, and this steel will be in production, both at the Donawitz works of the Österreichisch-Alpine Montangesellschaft and at the Linz works of the Vereinigte Österreichischen Eisen- und Stahlwerke, by the end of 1952. A production of 350,000 tons per year is expected.—H. R. M.

The Possibility of Improving Basic-Bessemer Steel by Adding Oxygen to the Blast. F. Linden. (*Stahl u. Eisen*, 1952, **72**, June 19, 773–776). Experiments in which the ductility and cold-drawing properties of basic-Bessemer steel blown with oxygen are shown to be the equal of those of open-hearth steel are described—J. P.

Manganese Concentrates from Open-Hearth Slags by Lime-Clinkering (Sylvester) Process. J. A. Ruppert. (*U.S. Bur. Mines Rep. Invest. No.* 4847, 1952, Feb.). The process involves addition of limestone to an open-hearth slag to give a $(CaO–3P_2O_5)/SiO_2$ ratio of approximately 2 and subsequent firing in an oxidizing atmosphere. The resulting clinker has a phase containing a preponderance of Al_2O_3, MnO, FeO, and MgO as oxides and can be separated magnetically after grinding from a non-magnetic phase consisting mostly of phosphorus containing dicalcium silicate. The results of laboratory and pilot-plant investigations are given. Quenching the clinker after firing improves the grindability. Very fine grinding is required to less than 325 mesh before separation of the oxide phase occurs. Although the manganese of the final concentrate was higher, there was some evidence that manganese recovery was lower from a flush slag than from a mixture of tap and flush slags.—B. G. B.

New Developments in Continuous Casting. O. Schaaber. (*Z. Metallkunde*, 1952, **43**, May, 181–190). A survey of the principles involved in continuous casting, and a review of existing methods of casting non-ferrous metals and steel is given. The most important factors in the design of plants are discussed, and reference is made to the special features involved in casting steel by this method. Particular aspects of the Junghans, Rossi, and Babcock and Wilcox plants are mentioned.—P. F.

Principles of Zone-Melting. W. G. Pfann. (*Trans. Amer. Inst. Min. Met. Eng.: J. Met.*, 1952, **4**, July, 747–753). In 'zone-melting,' one or more small molten zones traverse a long charge of alloy or impure metal. This manner of freezing is examined with respect to solute distribution in the ingot and with particular reference to purification and prevention of segregation. By 'zone-melting,' segregation can be either enhanced to provide a high degree of separation of solute and solvent, or it can be almost entirely eliminated.—G. F.

Effects of Premature Handling of Ingots on Rail Quality. J. G. Platon. (*Rev. Mét.* 1952, **49**, June, 436–438). The position of the critical zone in which internal cracking may occur is deduced for both ingot and rail and the position and localization of scaling on the rail surface are considered. Recommendations are made for further experiments.—A. G.

Assessment of Skin Thickness of Rimming Ingots. S. J. Smith. (*J. Iron Steel Inst.*, 1953, **173**, Jan., 16–18,). [This issue].

Surface Defects in Steel and their Relationship to the Different Stages of the Manufacturing Process. T. Dennison. (*J. Electrodep. Tech. Soc.*, 1951, **27**, 35–44). The author relates the various surface defects of hot- and cold-rolled steel products to the teeming, solidification, ingot reheating, and hot- and cold-rolling stages of manufacture.—J. P.

FOUNDRY PRACTICE

The Role of the Research Foundry Unit. G. A. Lillieqvist. (*Inst. British Foundrymen Preprint* 1025, June, 1952). The author outlines the organization and research programme of the research laboratory attached to the American Steel Foundries Co., East Chicago. The programme is divided into foundry, melting, and cleaning problems. Brief mention is made of work on temperature measurement, fluidity testing, factors affecting hot-tearing, welding electrodes, methods of crack detection, deoxidizers and desulphurizers, shell-moulding, phenolic resins, and carbon pick-up from cores.—E. T. L.

Productivity in British Steel Foundries. A. C. Thomson. (*Australian Found. Trade J.*, 1952, **3**, May, 3, 5). Increased productivity has been reported in many firms since the visits of teams to the U.S.A. Standardization, more mechanization, reorganization of plant, and improved working conditions are among the reasons for this improvement in output. The work of the British Steelfounders Assoc. is briefly outlined.

Production and Productivity in the American and Swedish Steel Casting Industries. S. H. Ljunggren. (*Jernkontorets Ann.*, 1952, **136**, June, 131–155). [In Swedish]. Production and productivity in the two countries are compared. Representative figures for man-hours/metric-ton of castings produced are given as 96 for the U.S.A. and 160 for Sweden. The disparity is attributed to greater mechanization, quantity production, larger American foundries, and more rapid working.—G. G. K.

Internal Stress in Castings.—(*Inst. British Foundrymen Preprint* 1037, June, 1952 : *Foundry Trade J.*, 1952, **93**, Oct. 23, 471–477). Measurements on double-flanged bars triangular grid castings, and hollow cylinders, indicate that temperature differences are an important cause of internal stresses, that stresses which are balanced by compression of the mould vanish on stripping, and that the stresses due to temperature gradients in simple castings may approach the yield strength of the material.—E. T. L.

Operating a Basic Cupola. S. F. Carter. (*Foundry*, 1952, **80**, May, 150–153, 250–260). The author describes two years' experience with a basic-lined cupola. The refractory costs may be almost twice as high (in the U.S.A.) as acid refractories, but basic operation gives less sulphur in the metal melted. Carbon and silicon control is almost as good as with

acid cupolas, and larger proportions of cast scrap can be used.

Better Control of Malleable Iron. L. Koch. (*Amer. Foundryman*, 1952, **22**, Aug., 36–38). A novel design of tuyere intended for blast-furnaces, but used here on a cupola, has been shown to give several advantages, including the ability to produce iron of more consistent composition. This tuyere has vanes to impart a twist to the air stream, *see* "Tuyere of Novel Design Improves Furnace Operation," *J. Iron Steel Inst.*, 1948, **159**, July, 324.—E. T. L.

Effect of Basic Cupola Operation on Tensile Strength of Gray Iron. W. T. Bourke and T. J. Wood. (*Foundry*, 1952, **80**, Apr., 86–87, 217–218). The authors' tests show that the strength is a function of the carbon equivalent, whilst sulphur has no significant effect, although the higher carbon contents associated with basic operation may be the indirect result of the low sulphur content obtained.—E. T. L.

Cupola Coke: With Particular Reference to High-Ash Coke. A. G. L. Lewis. (*Inst. British Foundrymen : Foundry Trade J.*, 1952, **93**, July 24, 89–93). Fluctuating coke quality, in particular the high-ash cokes in South Africa, make it important to consider the effect on cupola melting, where its main function is the addition of carbon. High-ash coke can be successfully used with suitable cupola design and operation, and with a low-ash carbon substitute such as pitch coke. An alternative is to use a coal-fired or reverberatory furnace instead of a cupola.—E. T. L.

Application of Spraying Technique to the Repair of the Cupola Furnace Lining. K. Krämer and O. Reinsberg. (*Giesserei*, 1952, **39**, July 24, 357–362). Three months' trials of the injection technique indicated that greater density and lower moisture content of the lining were achieved than in hand fettling ; shaping the hearth is easier, and a lower clay content is acceptable.—J. G. W.

Lighting the Standard Cupola without Causing Smoke. C. F. Semrau. (*Amer. Foundryman*, 1952, **21**, June, 49). To light up cupolas without smoke, cover the rammed-in sand bottom with paper which does not make smoke, and cover this with wooden boards. On top of these arrange rows of selected pieces of coke to give tunnels 12 in. wide, and about 20 in. high. The coke is covered with a cast-iron grate, on which rests the bed coke which reaches up the cupola to the tuyere level. The material is ignited by a gas torch through an opening in the cupola shell.—E. T. L.

Making a Synthetic Pig Iron. F. C. Barbour. (*Amer. Foundryman*, 1952, **22**, July, 54–55). Iron and steel scrap were melted together in a cupola and treated with lump graphite, ferrosilicon, and by-product coke. It was then cast into the metal moulds of a pig-casting machine. During the melting, the sulphur was removed with sodium sesquicarbonate; the result was a high-grade pig iron.—E. T. L.

HEATING FURNACES AND SOAKING PITS

Saturable Reactor Control of Electric Furnaces. R. M. Sills. (*Indust. Heating*, 1952, **19**, Apr., 608–622, 628 ; May, 808–818). The accurate control of temperature made possible with a saturable reactor is discussed. Reactor control is desirable where it is possible that temperature fluctuations may cause the work to be over or underheated. Other applications are : (1) Control of power input when the heating elements' resistance varies with temperature ; and (2) prolonging the life of containers exposed to radiant heating.—B. G. B.

Furnaces and Mechanical Equipment for Forging and Forming of Metals and Alloys. H. A. Clark. (*Indust. Heating*, 1952, **19**, June, 1026–1038). A definition of forging is first given with a discussion of forging temperatures. Forging equipment is classified into three groups—hammers, upsetters, and presses—each of which is described in detail. Batch and continuous furnaces for heating for forging are described, and the rôle of high-speed heating in the forging field is discussed. There is a short section on refractories.—B. G. B.

The Influence of Furnace Atmosphere on the Surface Finish of Round Billets and Tubes. W. Scheurer. (*Stahl u. Eisen*, 1952, **72**, July 31, 935–941). The influence of temperature and composition of heating furnace atmospheres on the severity and nature of scaling of steel is discussed. Bend tests have shown that the susceptibility of a steel surface to cracking on subsequent hot rolling of billets is increased with heating. The tests were carried out in oxidizing and sulphur-bearing atmospheres. The greatest tendency to cracking occurs at 1050° C. Additions of flue dust and sulphur to the furnace gases affected adversely the quality of the billet surface. Delays in the rolling programme, which cause billets to be held in the furnace for long periods, are also responsible for surface defects in the finished product. Oxidizing furnace atmospheres and a deformation temperature of 1050° C. have a very detrimental effect on the surface quality of tubes.—J. P.

Rotary Furnaces Feed Automatic Steel Treating Line. A. Q. Smith. (*Iron Age*, 1952, **169**, May 8, 122–124). The furnaces employed in a production line for 90 to 120 mm. shells are described. A gas-fired rotary forge furnace handles up to 24,000 lb. of steel/hr. on a 15-min. cycle at about 2300° F. The heat-treating and tempering furnaces (also rotary) process about 300 28-lb. shells/hr. at 1525° F. and 900° F. respectively.

Small Plants Favour Induction Furnaces. L. B. Reed. (*Iron Age*, 1952, **169**, May 29, 79–81). Small concerns in the Los Angeles area are said to favour induction melting rather than gas furnaces. Advantages claimed are lower maintenance costs, better temperature control, lack of fumes, lower operator fatigue, and less fire risk.—A. M. F.

Work-Handling Equipment for Radio-Frequency Heaters. E. Guyer. (*Brown-Boveri Rev.*, 1951, **38**, Nov., 331–332). Apparatus additional to the radio-frequency generators used for heating come under the heading of work-handling equipment. Apparatus of this kind for induction and for dielectric heating are described and illustrated.—R. A. R.

General Features of Radio-Frequency Heating and Its Industrial Applications. M. G. Favre. (*Brown-Boveri Rev.*, 1951, **38**, Nov., 317–319). The advantages and possible applications of the two methods of radio-frequency heating for the induction heating of metals and the dielectric heating of insulating materials are considered, and different factors determining production costs are investigated.—B. G. B.

Radio-Frequency Heating Equipment—Brown-Boveri Radio-Frequency Generators for Industrial Applications. M. G. Favre. (*Brown-Boveri Rev.*, 1951, **38**, Nov., 320–325). The generators marketed by Brown-Boveri and Co., Ltd., are described and details of some of the circuits are given.—R. A. R.

Power Required for the Radio-Frequency Heating of Metals. A. Leemann. (*Brown-Boveri Rev.*, 1951, **38**, Nov., 331–332). Formulæ and diagrams are given for determining the heating energy required for the induction heating of metal parts, and for determining the heat lost by radiation and convection.

Theoretical Aspects of Radio-Frequency Heating—The Principles of Induction Heating. E. Simmen. (*Brown-Boveri Rev.*, 1951, **38**, Nov., 361–364). The basic physical phenomena of radio-frequency heating are briefly examined and the problem of matching a load to a radio-frequency generator is discussed.—B. G. B.

Experience with Temperature-Regulated Forging and Hardening Furnaces for Drills and Chisels. L. Schmidt. (*Glückauf*, 1940, **76**, Apr. 13, 281–283). Experiences with temperature-controlled furnaces in a mine forge are described. The use of such furnaces is essential to guarantee a satisfactory life for drills and chisels. A saving of steel was experienced by the procedure described. The construction and layout of the furnaces are given.—R. J. W.

HEAT-TREATMENT AND HEAT-TREATMENT FURNACES

Latest Equipment for Melting and Heat-Treatment. (*Metal Treatment and Drop Forg.*, 1952, **19**, May, 229, 230, 236). A brief review is given of some of the many exhibits, in the metal treatment and melting fields, at the 1952 British Industries Fair.—P. M. C.

Practical Aspects of Tool and Die Heat Treatment. E. J. Pavesic. (*Amer. Soc. Tool Engineers : Steel Processing*, 1952, **38**, May, 240–243). The author discusses causes of failure in heat-treatment : Defective material ; poor tool or die design ; decarburization ; residual stresses ; surface marks acting as stress raisers ; and volume changes during treatment.—P. M. C.

Production Heat Treating of Connecting Rods. H. Chase. (*Mat. Methods*, 1952, **35**, June, 100–101). High output of automobile connecting rods is maintained, in an unspecified plant, by using a continuous radiant-tube furnace, a caustic soda quench, and a recirculating tempering furnace. The sequence of events is described and illustrated.—P. M. C.

Continuous Furnaces Economically Treat a Variety of Parts. C. W. Heilman. (*Mat. Methods*, 1951, **34**, Dec., 87, 88). The type, size, and shape of the workpieces passing through

a jobbing heat-treatment shop vary constantly and over a wide range. The author describes how a pair of continuous surface combustion controlled-atmosphere radiant-tube furnaces are used effectively to deal with such work. The conveyor speeds may be varied, as can the atmospheres and quenching media.—P. M. C.

Hardening Tank Tread Links in Quantity in Batch Furnaces. G. Brailsford. (*Indust. Heating*, 1952, **19,** May, 798–804). The tank tread links are hardened in quantities equivalent to a large continuous installation by using batteries of batch-type gas-fired, full-muffle furnaces with individual gas-atmosphere generators. Furnace and quenching facilities together with the hardening cycle are reviewed. A description is given of the muffle and tempering furnaces employed.—B. G. B.

Heat Treating, Setting and Shot-Peening of Mechanical Springs. F. P. Zimmerli. (*Metal Progress*, 1952, **61,** June, 97–106). Metallurgical operations in spring manufacture are considered in detail. All products are heat-treated, partly to relieve strains induced in the forming operation. The control of shape and the design of drawing arbors are discussed, together with the influence of shot peening.—B. G. B.

Graphitizing of Steel Surfaces. R. Oettel. (*Metalloberfläche*, 1951, **5,** May, A74–A75). A method suitable for producing steels having a surface layer resembling cast iron is described. The steels are alloyed with silicon, aluminium, titanium, nickel, copper, or cobalt, which facilitate the formation of granular temper carbon. Suitable heat-treatment is applied. The temper carbon was studied microscopically. The application of the method is primarily for tools requiring the toughness of steel and the high wear-resistance of cast irons.

Cementation with Sawdust. A. Kochin. (*Stanki i Instrument*, 1950, No. 11, 36). [In Russian]. Details are given of the procedure, evolved over a number of years, which enables successful use to be made of sawdust for cementation.—S. K.

Continuous Heat Treating System for Cast Armour Plate Being Installed. (*Indust. Heating*, 1952, **19,** Apr., 638, 650). Electrically driven furnace cars are used and serve as furnace hearths when closely coupled. The cars are equipped with an 8-in. refractory platform. Side and end sand seals provide a cool trough for motors and running gear, and thus permit normal insulation to be used.—B. G. B.

On the Problem of Choosing Optimum Conditions for the High-Frequency Heating of Steel. M. G. Lozinskii. (*Stanki i Instrument*, 1950, No. 7, 13–16). [In Russian]. A critical review is made of the main features of the induction heating of steel. After considering the nature of the process of induction hardening, the influence of the electrical conditions on the nature of the temperature distribution across a section of the work is discussed. Experiments on the connection between the heating temperature and the residual stresses are briefly described.—S. K.

High-Frequency Heating and Temperature Distribution in Surface Hardening of Steel. L. A. Dreyfus. (*Acta Polytechn.*, 1952, 101, *Electrical Engineering Series*, **4,** No. 5). Surface hardening of steel starts with the inductive heating of a surface layer above the Curie point which enforces a heat flow throughout the charge. When, after the prescribed heating time, the coolant is suddenly turned on, it should meet, not only with the correct surface temperature, but also with an approved temperature distribution within the surface layer, otherwise, the hardened layer will not attain the correct depth and structure. Thus, a scientific theory of surface hardening is bound to become a mathematical theory of heat flow, based upon the laws of inductive power in a red hot non-magnetic outer zone enveloping a magnetic core.—J. C. B.

Soldering, Annealing, Melting, and Sintering with Radio-Frequency Heating Equipment. G. Küchli. (*Brown-Boveri Rev.*, 1951, **38,** Nov., 339–343).

Radio-Frequency Case-Hardening—The Problem of Heat Conduction. A. Leemann. (*Brown Boveri Rev.*, 1951, **38,** Nov., 364–368). Calculations on the determination of heat conduction in steel during hardening by induction are explained and curves show the relation between depth of hardening and power input.—R. A. R.

Radio-Frequency Hardening of Steel. A. Leemann. (*Brown-Boveri Rev.*, 1951, **38,** Nov., 333–338). The induction hardening of gears, sewing-machine parts, and other items is described and illustrated, and the advantages of the process are pointed out.—R. A. R.

Induction Heating Installations. W. Stuhlmann. (*Z.V.d.I.*, 1952, **94,** July 1, 653–654). Induction heating equipment at the 1952 Hanover Fair is described; in particular, an induction furnace for a forge, a hardening furnace for bolts and spindles, and furnaces for surface hardening.—J. G. W.

FORGING, STAMPING, DRAWING, AND PRESSING

Heavy Forging Practice. G. A. Burnell. (Australian Inst. Metals : *Australasian Eng.*, 1952, Apr. 7, 46–56). The author first describes the advantages of the forging process, the various types of press in use, the manufacture and casting of ingots, and the ancillary equipment of a large forge plant. The heating, forging, and heat-treatment procedures are discussed, and some examples of high-class forgings produced recently in Australia are described. (10 references).—P. M. C.

The General Aspect of the Production of Heavy Forgings with Special Reference to One or Two Types. C. W. Hirst. (*Iron Coal Trades Rev.*, 1952, **164,** June 20, 1367–1373, 1383). The author considers the general problems in the manufacture of heavy forgings, from the points of view of the production and departmental managers. After outlining the organization required, attention is given to the type of ingot and assessment of the work ratio, the type of steel used, the heat-treatment applied, and the defects which may be encountered. Special reference is made to rotor forgings.—G. F.

How to Forge Steels and Alloys of High Nickel Content. J. Mayer. (*Hutnik*, (Prague), 1952, **2,** No. 5, 115–116). [In Czech].

Crankshaft Forging—Details of the New R.R. Continuous Grain-Flow Process. (*Australasian Eng.*, 1952, Apr. 7, 109, 111–113, 115, 117).

Material, Technical, and Finishing Problems in Cold Upsetting. G. Billigmann. (*Mitteilungen aus den Forschungsanstalten des Gutehoffnungshütte-Konzerns*, 1944, **10,** Oct., No. 8, 129–137). Longitudinal, shearing, internal, and surface cracks are important causes of failure in cold-forming production. They depend not only on the properties of the material, but often on the method of carrying out the upsetting process. The causes of such failures are given and suggestions made for their avoidance. The requirements of steel to be cold formed are considered.—R. J. W.

Screw Thread Manufacture from the Point of View of Recent Investigation of Materials. J. Billigmann. (*Mitteilungen aus den Forschungsanstalten des Gutehoffnungshütte-Konzerns*, 1943, **10,** Apr. No. 2, 29–40). An historical review shows the development of cold-formed screws, from 1780 up to modern methods of manufacture. The performance of commercial cold-drawn wire is discussed in relation to the strength requirements of the finished articles. The development of high-strength screws from a material viewpoint, and the classification of branded screws are considered in detail.—R. J. W.

Bonderizing as an Aid to Cold Forming. K. W. Michler. (*Österr. Masch. Elektrowirtschaft*, 1952, **7,** Mar., No. 6, 121). Bonderizing produces a phosphate surface coating with fine structure. Bonderized wire can be drawn at a faster speed with greater reductions, less die wear, and better surface finish. This treatment is equally helpful for other cold-forming processes such as deep drawing.—H. R. M.

Increased Productivity in Bar Drawing by Using Infinitely Variable Speed Control. F. Boehm. (*Stahl u. Eisen*, 1952, **72,** July 3, 797–804). The effect has been investigated of an infinitely variable speed control, as compared with a four-speed control, of a reciprocating motor drive on the productivity of a 15-ton drawbench. The influence of doubling the motor power, of the number of bars drawn at a time, and of the degree of reduction is discussed. The way in which processing time can be derived from the times required for the individual operations is described. The effect of the above variables on processing time and productivity is illustrated diagrammatically. Increased productivity is obtained with an infinitely variable gear because the speed can be matched exactly to the requirements of the material being drawn whereas with a stepped gear, a lower speed may have to be employed because the next would be too high. The increased utilization of the rating of the drive varies from case to case and, with the 60-h.p. motor used, reached a maximum at 24–27%.—J. P.

The Drawing of Steel Wire at Elevated and Sub-Normal Temperatures. F. C. Thompson, J. B. Carroll, and E. Bevitt. (*J. Iron Steel Inst.*, 1953, **173,** Jan., 36–51). [This issue].

Bibliography on Wire: Manufacture, Treatment and Properties. (*Iron Steel Inst., Bibliographical Series No.* 13a, 1952).

This bibliography continues Bibliographical Series No. 13, and covers the period 1947 to the end of 1951.—R. A. R.

Dimensions of Hard-Alloy Dies for Drawing Wire and Bars. V. P. Gerasimov. (*Stanki i Instrument*, 1950, No. 7, 28). [In Russian]. A very brief account is given of the successful use of unusually small hard-alloy drawing dies of sub-standard dimensions.—S. K.

ROLLING-MILL PRACTICE

Rolling of Metals. C. S. Ball. (*Sheet Metal Ind.*, 1952, **29,** June, 493–497). An abbreviated account is given of four lectures delivered at a Conference held at the University of Birmingham on March 18, 1952. These were : " Factors Affecting the Magnitude of Rolling Loads," by E. C. Larke ; " Preferred Orientations in Rolled Metals," by Prof. C. S. Barrett ; " Practical Interpretation of Rolling Theory and Experiment," by Prof. H. Ford ; and " Some Aspects of Automatic Gauge Control," by R. B. Sims.—P. M. C.

Heavy Steel Rolling. (*Elect. Rev.*, 1952, **151,** July, 3–12). The applications of electrical equipment to the production of steel in the slabbing mill at Port Talbot Works is described. Details are given of the electric motors on cranes, transfer cars, mill screwdowns and ingot cars. Notable inclusions are a mid-wire generator system for mill motor control, and a cascade exciter control for the slab shear motor. Brief mention is made of equipment for the maintenance of the mill and for cooling the motor room.—H. D. W.

Rehabilitation of a Slab Mill Without Loss in Production Time. A. Taylor. (*J. Iron Steel Inst.*, 1953, **173,** Jan., 69–80). [This issue].

Tight Motor Design Powers Fastest Cold Mill. B. D. Mickey. (*Iron Age*, 1952, **169,** May 22, 126–129). The motor drives for a 5-stand cold mill at the Fairless Works of the U.S. Steel Company are described. Commutation at high overloads has necessitated the use of two triple-armature motors on the fifth stand. Circular rotor punchings are mounted directly on the shaft arms to overcome the ventilating difficulties of the small-diameter rotors which are used to keep the inertia low. Demagnetizing and matching problems are also discussed.—A. M. F.

Rolling Friction between Materials of Different Elastic Moduli. A. Schäfer. (*Arch. Eisenhüttenwesen*, 1952, **23,** July–Aug., 253–256). The conditions existing between a cylinder and a plane, or between two cylinders under load, are treated mathematically, consideration being given to the friction at the line of contact ; both bodies have different elastic constants. The results show that the line of contact is composed of a central region of adhesion and two outer regions of slip. Reynolds also found the same division of the line of contact into three regions. The ratio of the width of the region of adhesion to the full width of contact is a function of the elastic constants and the coefficient of friction. Surface stress and shearing-force distribution are also calculated.—J. P..

The Relation between Bar Widths before and after the Pass in Rolling. E. Cotel. (*Z. Metallkunde*, 1943, **35,** Nov., 231–233). On the basis of different widening experiments it was established that the degree of widening depends on the tangent of the angle between 45° and 51° and that a fixed ratio exists between the bar widths before and after the pass. By means of the diagram given, it is possible for a mill engineer to know the increase in width with a high degree of accuracy. It was shown that the old formula of L. Geuze can be corrected by using the constant 0·384 (instead of the original 0·35).

Operation of a Ten-Inch Continuous Bar Mill. H. A. Carter. (*Amer. Iron Steel Inst. Regional Techn. Meetings*, 1950, 39–51). A description is given of the layout and operation of the 10-in. high-speed continuous bar mill at the Lackawanna plant of the Bethlehem Steel Co. The mill's range and limitations, and some of the problems encountered are discussed, and figures illustrating its performance are given.—G. F.

The Rendleman Rod Mill. N. Rendleman and A. Wilson. (*Iron Steel Eng.*, 1952, **29,** Aug., 77–82 : *United Effort*, 1952, **32,** Sept.–Oct., 3–8). A Rendleman rod mill consisting of 22 stands arranged in three divisions, with eight stands in the roughing train, eight in the intermediate train, and six in the finishing train is described. Details are given of a billet-bundle breaking and handling machine and of the roughing, intermediate, and finishing trains. Flow diagrams are also given.—M. D. J. B.

The Continuous Billet Mill at the Donawitz Rolling Mills of the Oesterreichisch-Alpine Montangesellschaft. (*Osterr. Masch. Elektrowirtschaft*, 1952, **7,** Mar., No. 4–5, 77–80). Modernization of the Donawitz mills is taking place in three stages : A 44½-in. blooming mill and bloom shear installed in 1950 ; a continuous billet mill installed in February, 1952 ; and a heavy section mill to follow later. Particulars of the billet mill, which consists of two 24-in. roughing and six 19-in. finishing stands, with edging mills after the roughing and second finishing stands, are given. Billets ranging from 50 to 120 mm. wide, or 6-mm. plates from 140 to 500 mm. wide can be rolled. With a speed of 3 m./sec. on the last stand, an output of 75,000 tons/month is obtainable.—H. R. M.

MACHINERY FOR IRON AND STEEL PLANT

Increased Interrupting Capacity in Fuses. J. C. Lebens. (*Iron Steel Eng.*, 1952, **29,** Aug., 70–74). After briefly describing the development of fuses, the author shows how the ideal protector should have ample time-lag at the lower overloads to obtain maximum capacity from the associated equipment, but virtually no time-lag under short-circuit conditions to clear heavy fault currents so rapidly that they will be limited to nominal values, incapable of injuring the circuit wiring or the electrical equipment.—M. D. J. B.

Crane Controls for Iron and Steel Works. L. N. Bramley. (*J. Iron Steel Inst.*, 1953, **173,** Jan., 53–68). [This issue].

Flying Shear Control at the Steel Company of Wales. S. A. G. Emms. (*G.E.C. J.*, 1952, **19,** July, 146–151). Details are given of the rotary flying shear, which can cut hot strip steel up to ¾ in. thick and 74 in. wide, the strip speed varying between 900 and 2000 ft./min. The control gear is described in detail, its operation is explained, and a full circuit diagram is shown.—T. E. D.

Electronic Control for Direct Current Motors. A. E. Ferguson. (*Electrical Engineer and Merchandiser*, 1952, **28,** Mar., 381–384). The general requirements for speed control are indicated. The use of rectifier circuits is discussed and a typical circuit arrangement is presented.—B. G. B.

Magnetic Floaters Separate 94 lb. Sheets. (*Machinist*, 1952, **96,** June 28, 982–983). The method of floating iron and steel sheets and blanks in a magnetic field, in order to separate them and facilitate handling one at a time, is now widely used for such purposes as feeding presses. The originators of magnetic floaters, James Neill & Co. (Sheffield), Ltd., have now introduced standard floater units in which the magnets are housed in die-cast aluminium cases. Both horizontal and vertical floaters are briefly discussed.—E. C. S.

LUBRICANTS AND LUBRICATION

A Study of the Oil-Film Formation in Gears by Electrical Resistance Measurements. T. B. Lane and J. R. Hughes. (*Brit. J. Appl. Physics*, 1952, **3,** Oct., 315–318).

The Engineering Aspects of Intimate Metallic Surfaces. H. E. Arblaster. (*Australasian Eng.*, 1952, Mar. 7, 43–58). The mechanism of cavitation erosion, and the venturi and vibratory methods of assessing the resistance of metals to this phenomenon are outlined. Various types of metallic wear are next described, and lubrication by thin metallic films is discussed. The frictional properties of the commoner bearing alloys are compared. Interposing films, boundary lubrication, and extreme-pressure lubricants are discussed, and the phenomenon variously called chafing, galling, and frettage corrosion is dealt with in some detail. Practical observations outlining preventative measures for various types of wear are made. (34 references).—P. M. C.

Running Test Experiences with Porous Oil-Retaining Bronze Bearings. (*Sci. Lub.*, 1952, **4,** Jun., 12–15). Details are given of specially designed equipment used by Bound Brook Bearings, Ltd., to test 'compo' porous bearings.—K. E. J.

Oil Flow in Plain Journal Bearings. (*Sci. Lub.*, 1952, **4,** May, 35). A simplified method of analysis for the rate of oil flow in plain journal bearings has been developed by the National Bureau of Standards. Applications of this to three basic designs of oil feed to the bearings are described.—K. E. J.

The Effects of Light on Lubricants and Fuels. R. K. Ross. (*Sci. Lub.*, 1952, **4,** Mar., 12–15, 27). In certain cases, the colour and bloom of a lubricant may be a guide to its quality, though caution must be used in view of modern refining methods. Methods of assessing the attributes of any light impulse are discussed. Descriptions are given o

the instruments used in petroleum colorimetry. Tables of colour indexes and conversion tables are provided.—K. E. J.

Centrifuging of Used Oils. A. C. Smith. (*Sci. Lub.*, 1951, **3,** Dec., 15–19). The treatment of circulating oils from large prime movers (*e.g.*, steam and gas turbines, steam reciprocating engines, and diesel engines) is discussed. The basic design principles, and operating details, of tubular and disc type centrifuges are described. Where the water content of the oil is small, performance can be improved by introducing condensed steam before centrifuging.—K. E. J.

WELDING AND FLAME-CUTTING

Higher Tensile Short-Link Steel Chain and Chain Slings. W. G. Biggart. (*Trans. Inst. Eng. Shipbuilders in Scotland*, 1951–52, **95,** 149–194). The author considers the problems arising in the manufacture of stud-link chain by resistance and flash butt welding. The assembly of all-steel slings, using atomic hydrogen welding for joining links is discussed.

Pressure Welding. R. F. Tylecote. (*Metal Ind.*, 1952, **81,** July 18, 43–46 ; July 25, 72, 73). The article deals with the theory and practice of joining metals by pressure by solid-phase welding, that is, at temperatures where there are no liquid slag or low-melting-point metallic constituents present. The presence of oxide, sulphide, or other films is the major deterrent to solid-phase welding, and methods of breaking down the films are discussed. (15 references).—P. M. C.

The Manufacture of Electric Welded Transmission Pipe. J. H. Middleton. (*Amer. Iron Steel Inst. Regional Techn. Meetings*, 1950, 79–90). A description is given of the plant used at the Republic Steel Corp. for the manufacture of expanded steel transmission pipe by the electric fusion submerged-arc welding process. There are three main steps to the process : Preparation and formation of flat plate into cylinders ; welding ; and sizing and finishing the pipe. These steps are considered separately.—G. F.

Good Materials Handling Permits More Output in Half the Space. (*Iron Age*, 1952, **169,** June 12, 124–125). A continuous belt conveyor used for a fabrication line for welded exhaust manifolds is described. This system only occupies half the space of a conventional pipe assembly layout.—A.M.F.

Automatic Welding with Contact Electrodes. W. P. van den Blink, H. Bienfait, and J. A. van Bergen. (*Philips Tech. Rev.*, 1952, **13,** Mar., 247–253).

The Construction and Wiring of Electric Welding Machines. J. F. Heath. (*New Zealand Eng.*, 1952, **7,** May 15, 201–203).

Metal Bonding. G. S. Newell. (*Aircraft Prod.*, 1952, **14,** July, 220–223). Developments of the Redux bonding process introduced by Aero Research, Ltd., are described, and its many applications are mentioned. Surface treatment before bonding is outlined, and a new vacuum technique developed for bonding, which will simplify tooling and eliminate the necessity for expensive presses and autoclaves, is described in some detail.—T. E. D.

A Résumé of the Ship Fracture Problem. F. Jonassen. (*Welding J.*, 1952, **31,** June, 316s–318s). The research programme of the American Ship Structure Committee to improve the construction of ships' hulls is outlined.—U. E.

Hydrogen in Mild Steel Weld Metal. A. L. Schaeffler, H. C. Campbell, and H. Thielsch. (*Welding J.*, 1952, **31,** June, 283s–309s). This is a review of published and unpublished information on the occurrence and effects of hydrogen in mild-steel weld deposits made by the shielded-metal arc welding process. (183 references).—U. E.

Characteristics of Submerged Arc Welding with Three-Phase Power. E. A. Clapp and N. G. Schreiner. (*Welding J.*, 1952, **31,** June, 479–485). The automatic submerged-arc welding process is described. Three-phase power is applied to two welding rods positioned in tandem over the seam to be welded. Each rod is independently driven by a rod-feed motor with control and guide tube. The effect of phase angle, phase sequence, power distribution between rods, and primary power factor is considered.—U. E.

Steel Mill Maintenance Welding During a Defence Period. R. L. Deily. (*Welding J.*, 1952, **31,** June, 476–478). The organization and planning of steel mill maintenance welding is discussed.—U. E.

Surface Tension and the Joining of Metals. E. R. Funk and H. Udin. (*Welding J.*, 1952, **31,** May, 247s–252s). The principles of capillarity and wetting are outlined. Methods for the determination of the surface tensions and interfacial tensions met with in joining metals are reviewed. The requirements in terms of surface tension for the preparation of brazing alloys are pointed out.—U. E.

Preheat *vs.* Low and High Temperature Stress-Relief Treatments. E. P. DeGarmo. (*Welding J.*, 1952, **31,** May, 233s–237s). In an investigation on the effect of stress relief heat-treatments, two 18 × 30 × $\frac{3}{4}$ in. plates were joined along their 30-in. edges by butt welding. The specimens were subjected to 1200° F. post-heat-treatment, to 400° F. preheat, and to low-temperature stress-relief treatment. All three treatments produced a marked improvement in the performance of weldments under static load conditions.—U. E.

MACHINING AND MACHINABILITY

Thermophysical Aspects of Metal Cutting. B. T. Chao, K. J. Trigger, and L. B. Zylstra. (*Trans. Amer. Soc. Mech., Eng.*, 1952, **74,** Aug., 1039–1054). Several controversial subjects are clarified by the experimental results presented. It has been found that the temperature distribution, both in the work material and in the deformed chip in the immediate vicinity of the tool–chip interface, depends upon a dimensionless number which is expressible as the ratio of the product of the cutting speed and feed to the thermal diffusivity of the metal cut. The ratio is called the thermal number, and its significance in metal cutting is illustrated and the limitations discussed.—D. H.

A Comparison of Parameters for the Machining of Grey Cast Iron. L. V. Colwell, H. J. Holmes, and F. B. Rote. (*Trans. Amer. Soc. Mech. Eng.*, 1952, **74,** Aug., 1029–1038). The investigation was designed to compare several types of data as parameters for predicting cutting speeds. Combined carbon, microhardness, and the graphitizing tendency hold the greatest promise of developing into reliable parameters, while Brinell hardness, tensile strength, drilling forces, and milling power are not likely to provide useful data.—D. H.

Tool Forces and Tool–Chip Adhesion in the Machining of Nodular Cast Iron. K. J. Trigger, L. B. Zylstra, and B. T. Chao. (*Trans. Amer. Soc. Mech. Eng.*, 1952, **74,** Aug., 1017–1027). The authors present the results of an investigation on the machining characteristics of nodular cast iron in both the as-cast and annealed condition. Tool forces, cutting temperatures, and tool–chip contact area are compared for different grades of cemented carbide tools. An adhesion phenomenon observed with this material provides evidence in support of the oxide film theory, and gives an explanation for some of the differences in wearing qualities of cemented carbide tools.

The Mechanics of Three-Dimensional Cutting Operations. M. C. Shaw, N. H. Cook, and P. A. Smith. (*Trans. Amer. Soc. Mech. Eng.*, 1952, **74,** Aug., 1055–1064). The chip-flow direction and the velocity and force relations for an oblique cutting tool have been compared with experimental results. The angle between the direction of chip flow and a normal to the cutting edge was found to be approximately equal to the inclination angle, for ordinary friction conditions, but to be progressively larger than the inclination angle as the friction decreased. The effective rake angle for an oblique tool was found to increase without a corresponding decrease in the included tool angle. The consequences of these observations are discussed.—D. H.

Production Planning in the Maintenance Machine-Shop or Jobbing Shop. D. S. Faulkner. (*Mech. World*, 1952, **131,** May, 210–212).

Britain, too, Is Developing Electro-Spark Machining. M. G. Seed. (*Machinist*, 1952, **96,** June 28, 977–981). Among the new processes promising a solution of the problem of machining 'unmachinable' materials is spark machining. Under the Rudorff patents, research on this technique is being carried out by Sparcatron Ltd., Gloucester. Some of the results are described, and the basic circuit, the servo circuit, stabilizing feed-back, spark grinding, surface pattern, and mould cavity production are dealt with.—E. C. S.

Electro-Spark Erosion. (*Metal Ind.*, 1952, **81,** July 11, 31–33). The principles of metal removal by electro-spark erosion are briefly outlined, and block diagrams showing the circuits are given. The adaptation of the method to turning, grinding, and other machining operations is outlined. Very hard materials, such as sintered carbides, are machined quite easily.—P. M. C.

Machining Large Forgings in Germany : Modern Equipment Reduces Cost and Increases Output. H. Dürr. (*Iron Coal Trades Rev.*, 1952, **165,** Aug. 8, 297–300). This is an abridged English version of a paper which appeared in *Stahl u. Eisen*,

1952, **72,** June 5, 687–695 (*see J. Iron Steel Inst.*, 1952, **172,** Nov., 352).

An Ingot Slicing Machine. (*Mech. World*, 1952, **131,** Apr., 162–163). A short description is given of the redesigned ingot slicing machine made by Craven Brothers (Manchester) Ltd. It is of simpler construction than its predecessor, and embodies several important improvements.—D. H.

CLEANING AND PICKLING

Electrical Equipment for Process Lines in Continuous Strip Mills. R. G. Rayden. (*Sheet Metal Ind.*, 1952, **29,** June, 485–492, 500). The author describes a wide range of equipment including motors, motor generating sets, exciters, and control gear. The use of such equipment in a continuous pickling line is described in detail.—P. M. C.

Shot Blasting Speeds Stainless Strip Cleaning. J. B. Delaney. (*Iron Age*, 1952, **169,** June 19, 133–135). A shot-blasting unit is used in the continuous hot rolled strip pickling line of Allegheny Ludlum Steel Corp. At strip speeds between 30 and 75 ft./min., depending on width, an average of 6 tons/hr. is cleaned. Advantages claimed include elimination of scalebreaking on straight chromium steels, reduced manpower, reduced floor area, and lower maintenance costs.

A Primer on Shot Peening. (*S.A.E. J.*, 1952, **60,** May, 20–22). The Shot Peening Division of the S.A.E. Iron and Steel Technical Committee have recently published a manual on this subject. It is a complete treatise covering theory, effects, uses, machines and materials, and current practices. The present article briefly reviews the contents of the manual.

How to Select Abrasives for Blast Cleaning Metals. V. F. Stine. (*Amer. Foundryman*, 1952, **22,** Aug., 39–41). The choice of abrasives is related to the type of metal to be cleaned, the shape of the part, the kind of material to be removed, and the surface finish required. The available abrasive materials are grouped into metals, chemicals, natural compounds, and natural grits.—E. T. L.

An Improved Cell for Electrolytic Polishing. L. W. Gleekman, G. E. Evans, and C. S. Grove, jun. (*Metal Progress*, 1952, **61,** June, 92–93). An easily constructed inexpensive cell for the electrolytic polishing and etching of metallographic specimens is described. It has been used successfully for gold, copper, brass, steel, cast iron, and stainless steel. The effects of rate of agitation, current flow, and cathode material are considered, and electrolytic composition, cell current, and cell voltage are correlated.—B. G. B.

How to Electropolish Stainless Steel. S. Storchheim. (*Machinist*, 1952, **96,** June 28, 998–999). The present theory and practical application of electrolytic polishing methods to the finishing of stainless steel is reviewed.—E. C. S.

From the History of Anodic Polishing. A. Kutzelnigg. (*Metalloberfläche*, 1951, **5,** May. B67–B68). A survey is given of the early developments in anodic polishing, with particular reference to the work of E. Beutel in memory of whom the article is written.—P. F.

Experience of Safety Measures For Flame Cleaning. (*Schweissen u. Schneiden*, 1952, **4,** Aug., 302–304). A description is given of the use of flame cleaning for removing rust from steel sections, and of the necessary safety measures when flame-cleaning is carried out in the open.—U. E.

PROTECTIVE COATINGS

The Cladding of Metals. R. D. Weber. (*Metallurgia*, 1952, **45,** Jan., 3–6). The principles of metal cladding are briefly discussed and the importance of the cladding temperature is stressed. Recent methods for the removal of undesirable surface layers before cladding are also mentioned. An outline is given of the processes used, particular attention being paid to solid-phase bonding ; a description is given of roll-cladding and pressure cladding. Liquid-phase cladding is also referred to, and mention is made of the properties and scrap recovery of clad metals.—B. G. B.

Hard Chromium—What the User Ought to Know. (*Usine Nouvelle*, 1952, **8,** Sept. 4, 29–30). The properties of electrolytic deposits of chromium are described and the techniques used in chromium plating are outlined and discussed. Finally, many industrial applications are given.—T. E. D.

Hard Chromium Plate and Bright Plating of Steel or Die Castings. A. G. Gray. (*Metal Progress*, 1952, **61,** June, 77–78, 170–172). An account is given of a high-speed chromium-plating bath which is automatically self-regulating within narrow limits with respect to mixed and co-operating catalylic acid radicles at any chosen chromic acid concentration and temperature. The properties and structure of chromium plate are discussed.—B. G. B.

The Hardness of Hard Chromium Deposits. H. Arend. (*Metalloberfläche*, 1951, **5,** May, B72–B76). A critical survey of the literature relating to factors influencing the hardness of chromium coatings is given. The influence of current density, bath temperature, and the oxygen and hydrogen contents of the deposit on the hardness is discussed.—P. F.

Plastic Deformation—Effect of Chromium Plating on Steel. (*Aircraft Prod.*, 1952, **14,** June, 218). The deleterious effects of chromium plating on the limits of plastic deformation in steel S.A.E. 4130 before fracture are outlined. The results of tensile-impact tests, bend tests, and crushing tests are given. Backing brought about some improvement, possibly because of the removal of hydrogen introduced during plating.—T. E. D.

Ion Exchange Saves Chromic Acid. (*Iron Age*, 1952, **169,** May 1, 152). A chromate recovery process developed by the Permutit Co. is briefly described. A cation exchanger removes metallic cations from the strong chromic acid anodizing solution, and an anion exchanger recovers the chromate from the dilute rinse solutions. In the process, hydrogen ions are exchanged for metallic ions.—A. M. F.

The Evolution of the Modern Hot-Dip Galvanizing Pot. W. G. Imhoff. (*Wire and Wire Products*, 1952, **27,** Aug., 769–774, 828–832). The development of modern hot-dip galvanizing pots in America is traced from the start of the century. Shapes, materials, and methods of construction are dealt with.—J. G. W.

A Portuguese Wire Galvanising Plant. (*Wire Ind.*, 1952, **19,** Sept., 828, 831–832). Particulars are given of new installations by the Incandescent Heat Co., Birmingham, at the Companhia Portuguesa de Trefilaria, Lisbon. These include a static annealing plant and a continuous annealing and galvanizing plant, including acid cleaning, water wash, and fluxing tanks.—J. G. W.

The Pre-Heating of Hot Rolls in the Tinplate Industry. (*Indust. Gas*, 1952, **15,** Jan., 97–99). Details are given of a burner system for use in the preheating of cast-iron rolls used in the tinplate industry. The results of trials using the equipment are discussed.—D. H.

Electrodeposited Tin Alloy Coatings Are Promising Alternates for Tin Plate. K. Rose. (*Mat. Methods*, 1951, **34,** Dec., 70–72). New tin–nickel (65–35), tin–zinc (80–20), and tin–copper (45–55) plates can be used on most common metals, they have many potential applications in both the industrial and decorative fields. The tin–nickel and tin–zinc plates are the more versatile pair, and details of plating solutions and applications are given.—P. M. C.

The Preparation of Tinplate for Painting. S. C. Britton. (*Sheet Metal Ind.*, 1952, **29,** June, 545–548, 558). Exhaustive tests have been carried out to assess the suitability of various surface treatments before painting. The treatments included vapour degreasing, alkaline washing, acid washing, and cathodic etching. After pretreatment and painting, bending, cupping, and scratch tests were employed to estimate the quality of adhesion of the paint. The full results are tabulated. Cathodic etching and acid washing are the most effective treatments.—P. M. C.

POWDER METALLURGY

The Technique of Pressing and Sintering of Metallic Powders. F. Šindler. (*Hutnik* (Prague), 1952, **2,** 7–8, 176–178). [In Czech].—P. F.

Five Ways to Make Iron Powder. B. T. du Pont and R. Fulton. (*Iron Age*, 1952, **169,** Apr. 24, 135–139). The production of iron powder at the Plastic Metals Div. of the National Radiator Co., Johnstown, Pa., is by five separate methods. These are : (1) Electrodeposition of pure iron from steel plates ; (2) reduction of millscale in a rotary kiln ; (3) atomization of melted scrap ; (4) reduction of millscale or iron ore in saggers ; and (5) the gaseous reduction of millscale.

Powder Metallurgy and Metal-Ceramic Products. R. Kieffer. (*Metall. u. Erz*, 1940, **37,** Feb., No. 4, 67–70 ; Mar., No. 5, 88–92). The development of powder metallurgy is described, with some early examples. The theory of sintering is briefly outlined, and the principal applications are summarized. The method of manufacture of some metallic powders is described.

The Production and Application of Magnetic Powders. G. R. Polgreen. (*G.E.C. J.*, 1952, **19,** July, 152–169). The many uses of magnetic powders in telecommunication equipment

and many branches of electrical engineering are outlined. Reference is made to pure iron powder of various grades and a new copper–nickel–iron alloy Gecalloy III. Methods of production used and equipment developed by G.E.C. and Salford Electrical Instruments, Ltd., are described and illustrated.—T. E. D.

Powder Metallurgy as a Research Tool. H. W. Greenwood. (*Metallurgia*, 1952, **46,** July, 8–10). Powder metallurgical technique offers advantages in the economy of materials and apparatus and permits close control of conditions. The effect of additions of minor constituents can be tested and grain size in metals or alloys can be controlled accurately. Precipitation hardening of alloys has been investigated and an example is given of the production of compressor blades for jet engines by infiltrating the porous iron skeletons with a liquid copper–aluminium alloy (4% Al) at 1040° C.—B. G. B.

Speedier Powder Quality Control Made Possible. (*Metallurgia*, 1952, **45,** Jan., 49–51). Particle-size distribution affects the quality of a powder and must be determined for effective control to be exercised. A description is given of an instrument designed with the object of putting sub-sieve analysis on a practical routine basis. The photosedimentometer uses a compensating optical system to measure the sedimentation photoelectrically. An automatic recording potentiometer is incorporated. The instrument is suitable only for the analysis of powders which can be made to settle out freely in some convenient liquid.—B. G. B.

PROPERTIES AND TESTS

A New Version of 'Strength of Materials.' Archibald C. Vivian. (*Metallurgia*, 1952, **45,** Jan., 29–37). The author considers that the present system of 'Strength of Materials' is unrelated, unsystematic, and faulty in conception, and presents the case for a new version of the subject. It is suggested that mechanical properties are related by three constants for each material using the true stress–strain curve ($f = ks^n$) (where f = stress and s = logarithmic strain) and Poisson's ratio (m). The three constants k, n, and m, determined for a sufficient range of temperatures and loading rates can be made to serve for all mechanical properties of a material. Examples of the new proposals are given.—B. G. B.

Large Equipment for Prolonged Tests (Called G.I.M.E.D.) of l'Association des Industriels de Belgique (A.I.B.) L. Baes and Y. Verwilst. (*Ossature Métallique*, 1951, **17,** May, 267–275). Large equipment for testing beams and sections of wood, light metal, and steel, constructed for the Association des Industriels de Belgique, and capable of applying combined stresses of the static and fatigue types is described.

Mechanical Testing of Solid Materials. W. Ramberg. (*Appl. Mech. Rev.*, 1952, **5,** June, 241–244). Methods of determining Young's modulus, Poisson's ratio, and the shear modulus from static tests at room temperature are given. The measurement of damping capacity and plastic yielding is described, and fracture and inspection for damage are discussed. (117 references).—B. G. B.

An Interferometer for Calibrating Extensometers. W. K. G. Floor. (*J. Sci. Instruments*, 1952, **29,** June, 200). Details are given of a reliable apparatus for the continuous calibration, in different positions, of two extensometers. The accuracy of the instrument is 0·00005 mm.—H. D. W.

Results of Works Trials on IM-12A Tensile Testing Machines. M. M. Kobrin and A. S. Borovich. (*Zavodskaya Laboratoriya*, 1950, No. 3, 378–380). [In Russian]. A description is given of a series of tests carried out on new tensile testing machines under works conditions. Suggested improvements are listed.

Lever Dynamometer for Checking Testing Machines and Apparatus. M. S. Bludorov. (*Zavodskaya Laboratoriya*, 1950, No. 3, 382–384). [In Russian]. An experimental lever dynamometer is described; it can deal with loads up to 150 kg. giving a maximum error of less than 0·05% of the force being measured.—S. K.

New Specimens for Single-Axis Compression Testing. K. K. Likharev. (*Zavodskaya Laboratoriya*, 1950, No. 3, 338–345). [In Russian]. Various attempts to improve the design of specimens for testing in single-axis compression are critically considered and a new type of specimen is proposed which may also be used for tensile tests. This is in the form of a thick-walled tube with ends having conical surfaces. The compression plates are also conical and have the same angle. With correctly chosen angles and careful centring, the specimens remain cylindrical until fracture. The application of this new method to soft, normalized, hardened, and tool steels is described.—S. K.

X-Ray Examination of the Surface of the Fractures of Impact Test Samples. M. P. Zheldak. (*Doklady Akademii Nauk S.S.S.R.*, 1952, **83,** 6, 843–845). [In Russian]. Samples of highly alloyed semi-ferritic steel EI-428 in the brittle and ductile states and samples of carbon steel '20' were investigated.—V. G.

A Calibrating Device for Impact Testing Machines. G. L. Brown. (*J. Sci. Instruments*, 1952, **29,** May, 161). A device is described for calibrating the common form of Izod impact tester. The principle is the determination of potential energy by the measurement of chordal length and thrust.

The Influence of the Quality of the Machined Surface on the Resistance to Failure Under Single or Repeated Impacts. G. I. Pogodin-Alekseev and A. V. Panfilov. (*Stanki i Instrument*, 1951, No. 4, 22–23). [In Russian]. An investigation of the influence of surface quality on the resistance to impact of smooth and notched specimens of two carbon steels in the temperature range +20° to −160° C. is reported. The influence was considerable for both single and repeated impacts, being somewhat less for the latter. Improving the surface lowered the mean temperature of the brittle temperature range. There is an optimum surface quality which secures adequate resistance to failure without making machining difficult.—S. K.

Nitrogen Content and Low Temperature Brittleness of Steel. (*Welding J.*, 1952, **31,** June, 474–475). This is a summary of results which were obtained with notched specimens in Charpy impact tests. It was found that increased nitrogen content (in the form of aluminium nitride) improved the low-temperature notch toughness and lowered the transition temperature, but other nitrides were detrimental.—U. E.

Plasticity of Steel and Quality of Surface Finish. F. P. Rybalko and M. V. Yakutovich. (*Doklady Akademii Nauk S.S.S.R.*, 1949, **64,** 5, 673–674). The influence of minor surface defects upon the extent of plastic deformation before rupture has been investigated. The results of experiments made on a Cr–Ni–Mo–V structural alloy steel, after different heat-treatments, showed that insignificant scratches statistically distributed on the surface of a specimen subjected to torsion exert a strong effect on the plasticity of the steel.—V. G.

The Formation of Immobile Dislocations During Slip. A. H. Cottrell. (*Phil. Mag.*, 1952, **43,** June, 645–647). Lomer has pointed out that certain dislocations on intersecting slip planes in the face-centred cubic lattice can join to form new dislocations. It is here proposed that these new dislocations dissociate into groups of imperfect ones, which cannot move because of the arrangement of their associated stacking faults. These immobile dislocations may be important in work-hardening.—E. T. L.

The Growth and Present State of Three-Dimensional Photoelasticity. M. M. Frocht. (*Appl. Mech. Rev.*, 1952, **5,** Aug., 337–340). The method is no longer confined to surface stresses or to principal shears or to sections of symmetry. It is now possible to determine the actual principal stresses at each and every point of a general space problem. The only limitations at the present time are the difficulties in making the model and in the application of the loads. If a model can be made and the loads can be properly reproduced, the stresses can be determined with a high degree of accuracy, initial stresses forming the major source of error.—J. C. B.

Testing Model Lacquers. L. M. Nevyazhskaya. (*Zavodskaya Laboratoriya*, 1950, No. 3, 368–369). [In Russian]. Recommended additional tests to determine the water permeability, resistance to wear, and ageing properties of lacquers used for stress analysis are briefly described.—S. K.

Nucleation and Growth of Flow and Fracture Markings. W. George. (*Indust. Eng. Chem.*, 1952, **44,** June, 1328–1331). 'Models' of the character of microscopic processes of plastic flowing can be based on macroscopic observations of the development of local plastic flowing and fracturing in polymeric metals and solids. Delayed yielding in metals and polyamides is reviewed. Emphasis is given to the nucleation of macroscopic flow and fracture elements in regions of stress concentration in advance of primary flow or fracture events. These mechanisms are illustrated by reference to fatigue fracture, creepy fracture, horizontal flow markings, craze cracks, fracture pairs, and showers. (33 references).

K. E. J.

Brittle Fracture in Mild Steel: Study of Tests to Determine Susceptibility. C. Schaub. (*Iron Coal Trades Rev.*, 1952, **165,** Aug. 8, 321–322, 324). The important phenomenon of brittle fracture in mild steels used for structural welding is discussed. The fracture characteristics of α-iron are considered, and the tests used to determine the susceptibility to brittle fracture are reviewed, particular reference being made to the work of T. S. Robertson.—G. F.

Investigation of the Notched Slow-Bend Test as a Brittle Fracture Test. J. E. de Graaf and J. H. van der Veen. (*J. Iron Steel Inst.*, 1953, **173,** Jan. 19–30). [This issue].

A Yield Criterion for Ductile Metals Based upon Atomic Structure. M. C. Shaw. (*J. Franklin Inst.*, 1952, **254,** Aug., 109–126). A strength theory for ductile metals is presented which takes into account the short-range inhomogeneities that are present in all commercial metals. Examples are presented to illustrate the shortcomings of the conventional maximum shear-stress and distortion-energy theories. The new theory predicts a variation in yield stress with specimen size, and it is shown why such a size effect is observed with torsion specimens but not with tensile specimens of usual size. The relation of the new theory for ductile metals to the statistical theory of Weibull for brittle materials is considered.—J. C. B.

On the Stress–Strain Relations of Plastic Deformation. J. P. Benthem. (*National Luchtvaarlaboratorium, Amsterdam*, 1951, Report S.398, 1–88). The analysis of strain, the stress tensor, and the use of tensor invariants are explained. Various aspects of yield limits are examined. Yield limit is related to the stress–strain relations according to the deformation of flow theories, and the latter are derived from experiments in which the ratio of the stress components is preserved. An anisotropic theory is discussed, and some experiments to decide between the various theories are described. (31 references).—T. E. D.

Determination of Internal Stresses in Finished Articles. H. Bühler. (*Arch. Eisenhüttenwesen*, 1952, **23,** July–Aug., 293–297). Determinations of internal stress by the boring method on solid steel cylinders have shown that these can be estimated on a portion cut from the end of the cylinder. Provided that the cylinder is long enough to bear this shortening, a piece equal in length to twice the diameter is cut off after finishing and tested by the boring method. It is thus possible to obtain, without undue waste, a clear assessment of the magnitude and distribution of internal stresses without making the article unusable. A similar procedure is possible for hollow cylinders.—J. P.

The Applicability of Technical Methods for Measuring Internal Stresses in Metallic Objects. H. Bühler. (*Stahl. u. Eisen*, 1952, **72,** July 31, 947–952). Various proposed methods for measuring internal stress are described and their applicability is studied. Most of them are suitable only in special instances for providing information on the magnitude and distribution of internal stresses over the whole cross-section without extensive machining. Auxiliary methods, such as those devised by Klein, Müller, and Stablein, are sometimes applicable. The most useful procedure for examining cylindrical objects is the boring method of Sachs. The use of resistance strain gauges gives greater accuracy and shortens working time.—J. P.

A Criterion for the Failure of Cast Iron. J. C. Fisher. (*A.S.T.M. Bulletin*, 1952, Apr., 74–75). According to the theory that metals undergo plastic deformation before fracture, cast iron breaks as soon as it flows. Therefore fracture stresses must be identical with those required to initiate flow. The distortion/energy-flow criterion, applied to regions of concentrated stress near graphite plates embedded in the iron matrix of cast iron, leads to calculated yield-stress values that are in reasonable agreement with experimental combined stress-fracture values.—B. G. B.

The Application of Resistance Strain Gauges to Torque Measurement. R. H. Warring. (*Mech. World*, 1952, **131,** Apr., 158–159). Since torsional strain is related to torque, the strain gauge can be used directly as a torquemeter. The principles involved in the application are explained.—D. H.

Some Experiments on the Resistance of Metals to Fatigue under Combined Stresses—Part I. H. J. Gough and H. V. Pollard. (*Ministry of Supply Aeronaut. Res. Council Reports and Memoranda*, 1951, 6–97). This describes a comprehensive research into the fatigue behaviour of a selection of engineering steels and two alloy cast irons under combined bending and torsional stresses alternating in phase, the mean stress of both types of stress cycle being zero in every case. A high-speed testing machine, referred to as the 'No. 1 Combined Stress Fatigue Testing Machine' was developed, and is described in detail.—J. C. B.

Some Experiments on the Resistance of Metals to Fatigue under Combined Stresses—Part II. H. J. Gough and W. J. Clenshaw. (*Ministry of Supply Aeronaut. Res. Council Reports and Memoranda*, 1951, 98–141). A description is given of the research into the resistance of a Ni–Cr–Mo–V aircraft steel (Specification S.C5A) to combined fatigue stresses in which four independent variables have been investigated. These variables were: (1) Reversed bending stresses; (2) reversed torsional stresses; (3) static bending stresses; and (4) static torsional stresses superimposed on these cyclic stresses. The programme consisted essentially of (*a*) tests on solid specimens, and (*b*) tests on three forms of hollow specimens each containing a radial oil hole, a transition fillet of small radius, and a six-splined shaft, respectively.—J. C. B.

European Research on the Behaviour of Metals Yields Promising Results. T. J. Dolan. (*Mat. Methods*, 1952, **35,** June, 93–96). The author, who recently toured England, Scotland, Switzerland, and Sweden, records his views on some fatigue- and creep-testing methods seen there.—P. M. C.

Tensile-Compressive Fatigue Strength and Changes of Properties of Steel after Cold Deformation at Different Rates. H. R. Sander and M. Hempel. (*Arch. Eisenhüttenwesen*, 1952, **23,** July–Aug., 299–320). An investigation has been undertaken to determine the effect of prestressing, particularly at different rates, on the fatigue strength of steels. Tests were carried out on soft iron, 0·4% C, unstable austenitic 18/8 and stable austenitic 15/27 chromium–nickel steels. Deformation rates were from 0·005% to 20,000% per sec. and the loads chosen were such as to be just above the yield stress, just below the tensile strength, and in the region of elongation. The alternating compression strength and fatigue limit of the materials was changed by preliminary extension; the nature and extent of these changes depended on the amount of extension, the rate of deformation, and the type of material. The increased fatigue strengths of iron and unalloyed steels were greater after dynamic stressing than after static deformation. With the unstable austenitic steel, the results were the opposite. The results of magnetic and hardness measurements and determinations of surface stress by X-ray methods are used to interpret the behaviour of the specimens.—J. P.

On the Direction of Fatigue Cracks in Polycrystalline Ingot Iron. F. A. McClintock. (*J. Appl. Mech.*, 1952, **19,** Mar., 54–56). A statistical analysis is developed to show how a microscopic shear failure can result in the apparent tensile failure of polycrystalline iron in rotary bending fatigue tests.

Pre-tensioning for Preventing Fatigue Failure in Bolts. W. A. P. Fisher, R. H. Cross, and G. M. Norris. (*Aircraft Eng.*, 1952, **24,** June, 160–163). The prevention of fatigue in bolts by controlled pre-tensioning is investigated theoretically. It is shown that pre-tensioning reduces the alternating load in the bolt. The results of fatigue tests on ¾-in. B.S.F. bolts are reported fully and show that fatigue failure can be prevented. The importance of maintaining pre-tension in service is emphasized.—T. E. D.

Stress Concentrations in Steel Under Cyclic Load. E. Orowan. (*Welding J.*, 1952, **31,** June, 273s–282s). A graphical method is given for obtaining stress and strain amplitudes during cyclic loading at local stress peaks exceeding the elastic limit, and particular reference is made to its application to steel pressure vessels.—U. E.

Dynamic Arrangements of Fatigue-Testing Machines. M. E. Garf. (*Zavodskaya Laboratoriya*, 1950, No. 3, 331–338). [In Russian]. Fatigue-testing methods and the reproducibility of results between different machines are critically examined. A classification of fatigue-testing machines, based on their dynamic characteristics, is proposed. Each group is illustrated by a number of designs which have found wide application in practice.—S. K.

On the Evaluation of Fatigue Strength. A. A. Novik. (*Zavodskaya Laboratoriya*, 1950, No. 3, 352–355). [In Russian]. The difficulty of deducing the performance of machine parts from fatigue test data is considered, and a series of experiments on factors influencing fatigue strength is described. Two smooth 14-mm.-dia. specimens, held at different temperatures, were simultaneously tested at 3000 cycles/min., static and impact properties also being determined. Increasing tempering temperature decreased the

number of reversals to fracture, the fatigue strength decreasing sharply in the presence of only a very small decarburized zone.

The Influence of Shot Peening on the Fatigue Properties of Steel. W. J. Harris. (*Metallurgia*, 1952, **45**, June, 299–300). Fatigue tests were carried out on three different gauges of patented carbon spring steel wire and endurance ratios calculated in the ' as drawn ' and ' shot-peened and tempered ' conditions. A critical survey is made of shot-peening in relation to fatigue. Beneficial results may be obtained in certain cases by shot-peening to improve the resistance of components to failure by fatigue.—B. G. B.

Strength, Structure, and Composition of Unalloyed Grey Iron. H. T. Angus. (*Inst. British Foundrywuan Preprint* 1027, June, 1952). The author explains the effect of composition and structure on strength and shock resistance. The effect of silicon and phosphorus is considered as being equivalent to that of one-third of equal amounts of carbon. The type of structure that is formed is related to the composition and the thickness of the casting.—E. T. L.

Effect of Chemistry and Section Size on Properties of Ductile Iron. D. J. Reese, F. B. Rote, and G. A. Conger. (*S.A.E. Quarterly Trans.*, 1952, **6**, July, 385–394). Details are given of experimental work on the effects of carbon, silicon, and phosphorus contents, and of section size, on the mechanical properties of ductile cast iron. Carbon in the range 2·75 to 4·10% had a minor controlling influence on properties. Silicon, through its influence on the matrix structure and its solid solution hardening effect, when increased from 1% to 5%, produces linear increases in tensile and yield strength and hardness, and lowers the ductility. Increasing phosphorus from 0·04 to 0·40% increases hardness and decreases ductility. Some section sensitivity is exhibited, the strength falling slightly with increasing section thickness.—P. M. C.

METALLOGRAPHY

A New Device for Metallic Shadow Casting. T. Hibi. (*Rev. Sci. Inst.*, 1952, **23**, July 383–385). The metal that is being evaporated to produce the shadow casts in electron microscopy is directed on to the specimen by a long glass nozzle, all work being done in a low vacuum bell jar. In this way, metals which have not hitherto been feasible for shadowing materials can now be used, and improvement with usual metals has been achieved.—J. C. B.

Comparison of Several Methods of Determining Austenitic Grain-Size in Steel. F. Labonek and L. Jeníček. (*Hutnické Listy*, 1952, **7**, 4, 171–178). [In Czech]. The methods of determining the grain size of austenite are surveyed, and some of them are used on two high and one medium carbon steels. The results obtained are compared and discussed. The methods considered include those of Bain, Bain and Villel, Austin and Day, Herasymenko, McQuaid-Ehn, Eckel and Paprocki, and a fracture method. (92 references).—P. F.

New Procedure for Improving the Possibility of Isolating Non-Metallic Inclusions in Iron and Steel Products. R. Zoja. (*Ricerca Scientifica*, 1950, **20**, Jan.–Feb., 136–137). [In Italian]. Brief details are given of a suggested procedure for studying non-metallic inclusions. The method would consist in melting the inclusions and examining these while retaining the metal matrix in the solid state. The author suggests that since the heat-treatment of metals has an important effect on inclusions, it should be considered as a method for research into the behaviour of non-metallic inclusions.—M. D. J. B.

A Direct Method for Measuring the High Voltage Stability of the Electron Microscope. T. Mulvey. (*J. Sci. Instruments*, 1952, **29**, May, 149–150).

Applied Infra-Red Photography. W. Clark. (*Research*, 1952, **5**, July, 304–312). Among numerous applications of infra-red radiation photography is mentioned transillumination to study defects in etched specimens of metal fusion welds. It is also used to study porosity in tinplate.—J. C. B.

A New Anodic Method for the Transfer of Oxide Films from Heat-Tinted Iron to Glass, or Plastic. U. R. Evans and R. Tomlinson. (*J. Appl. Chem.*, 1952, **2**, Mar., 105–109). In the new anodic method, the specimen carrying the oxide film to be transferred is cemented to glass, and the whole of the metal is dissolved away by anodic action, leaving the film attached to the glass.—E. C. S.

Electron Diffraction and Grinding of Metals. R. Courtel. (*Indust. Diamond Rev.*, 1952, **12**, Sept., 196–200). A grinding wheel to work under vacuum or in controlled contaminating atmospheres is described. It is used in conjunction with a modified electron diffraction camera. This apparatus is applied to examine a metal surface prepared *in vacuo* and the effects of contaminating gases on its surface.—J. C. B.

The Use of the Three-Stage Electron Microscope in Crystal-Structure Analysis. J. F. Brown and D. Clark. (*Acta Cryst.*, 1952, **5**, Sept., 615–619). The method, which combines electron diffraction and microscopy, enables very small crystals, less than 1 μ across and 1000 Å. thick, to be studied. The diffraction patterns obtained gave information concerning unit-cell size and symmetry. Examples are given and illustrated, the method being applied to alloy steels and carbides. The difficulties and limitations of the method are discussed.—T. E. D.

X-Ray Crystallographic Investigation of Carbides in Tungsten Steel. K. Kuo. (*Jernkontorets Ann.*, 1952, **136**, June, 156–168). [In Swedish]. Carbide reactions in tungsten steels, studied during isothermal transformation from austenite at 700° C. and during tempering at various temperatures after quenching, are discussed on the basis of the chemical compositions of the carbides and the matrix.—G. G. K.

Demountable X-Ray Tube for Crystallography. T. B. Rymer and P. G. Hambling. (*J. Sci. Instruments*, 1952, **29**, June, 192–194). A medium-power, demountable, shockproof X-ray tube is described. The construction is simple, and the various parts fit together to form a very rigid unit.—H. D. W.

Analysis of Certain Errors in the X-Ray Reflection Method for the Quantitative Determination of Preferred Orientations. W. P. Chernock and W. A. Beck. (*J. Appl. Phys.*, 1952, **23**, Mar., 341–345). The previously unexplained decrease in the diffracted intensity with increasing tilting angle for specimens with random orientation can be accounted for on the basis of an analysis of defocusing effects. This is checked experimentally, and the importance of accurate specimen alignment is emphasized.—E. T. L.

Some Observations on Slip Lines in Iron. H. W. Paxton, M. A. Adams, and T. B. Massalski. (*Phil. Mag.*, 1952, **43**, Feb., 257–258). Photographs illustrate the change in the form of slip lines, caused by a change in the state of smoothness of the iron surface. It is necessary to polish electrolytically to a depth of about 10 μ to avoid coarse slip lines on subsequent extension.—E. T. L.

Furnace Construction and Thermocouple Arrangements for a High Temperature X-Ray Camera. Z. S. Basinski, W. B. Pearson, and J. W. Christian. (*J. Sci. Instruments*, 1952, **29**, May, 154–155).

A Weissenberg X-Ray Diffraction Camera. C. A. Beevers. (*J. Sci. Instruments*, 1952, **29**, July, 230–233). A camera suitable for the speedy production of oscillating crystal and Weissenberg X-ray diffraction photographs is described. By the omission of the equi-inclination feature, the distance of the focal spot to crystal is only 100 mm. and exposure time is short.—H. D. W.

An Adjustable Debye-Scherrer X-Ray Camera for Specimens of Large Diameter. A. Taylor. (*J. Sci. Instruments*, 1952, **29**, July, 236). A modification to the upper plate of a typical Debye-Scherrer powder camera is described, which enables specimens up to $\frac{1}{2}$ in. in dia. to be examined by the glancing-beam technique.—H. D. W.

X-Ray Powder Camera of the Debye-Scherrer Type. Z. Bojarski, E. Romer, and Z. Ziolowski. (*Prace Instytutu Metalurgii*, 1952, **4**, 2, 145–151). [In Polish]. The important parts of a good X-ray powder camera are discussed. A description and technical data of a camera designed and manufactured by the authors is given.—V. G.

A Modified Specimen Mounting for a High Temperature X-Ray Camera. R. L. Berry and W. G. Henry. (*J. Sci. Instruments*, 1952, **29**, Apr., 132). A modification to the standard 19-cm. room temperature Unicam camera specimen mounting is described.—H. D. W.

X-Ray Anti-Reflections in Crystals. G. N. Ramachandran and G. Kantha. (*Proc. Indian Acad. Sci.*, 1952, **35**, Mar., 145–158). The theory that the intensity of the transmitted beam may exhibit a peak larger than the background when a Bragg reflection occurs in an absorbing crystal is discussed.

Study of the Imperfections of Crystal Structure in Polycrystalline Materials: Low Carbon Alloy and Silicon Ferrite. J. J. Slade, jun. and S. Weissmann. (*J. Appl. Phys.*, 1952, **23**, Mar., 323–329). A new double X-ray spectrometer method is applied to the study of angular misalignment of crystal structure in alloys. The method is extended to include arrays of spots on the Debye-Scherrer lines at high

elevations. Data obtained show a dependence of perfection on the annealing temperature. This information is related to the influence of cold-rolling on subsequent annealing.—E. T. L.

Effect of Molybdenum and of Nickel on the Rate of Nucleation and the Rate of Growth of Pearlite. R. W. Parcel and R. F. Mehl. (*Trans. Amer. Inst. Min. Met. Eng.: J. Met.*, 1952, **4,** July, 771–780). The authors have measured the rates of nucleation and growth of pearlite over a temperature range in a series of eutectoid alloy steels containing up to 0·77% Mo and 2·95% Ni, both with and without manganese. Both rates are decreased by molybdenum and nickel, at all temperatures and in all alloys. The rate of growth is not determined primarily by the interlamellar spacing, and decreases exponentially with increase in alloy content. The evidence is strongly in favour of a segregation of the alloying element concomitant with the growth of pearlite.—G. F.

Thermal Stabilization of Austentite in Carburizing Steels. H. M. Otte and T. Ko. (*J. Iron Steel Inst.*, 1953, **173,** Jan., 31–35). [This issue].

Causes of the Weakening of the Intensity of X-Ray Lines of Martensite. V. A. Il'ina, A. V. Kritskaya, and G. V. Kurdyumov. (*Doklady Akademii Nauk S S S.R.*, 1952, **85,** 4, 773–775). [In Russian]. To determine the character of distortion of the crystal lattice of martensite, measurements of the intensity of X-ray reflections from quenched steels (C 0·35% and 0·41%) at temperatures of + 23° C. and −185° C. were made. It is concluded that the martensite lattice is characterized by the existence of lattice stresses of the third order. The lattice stresses are increased by the presence of carbon atoms, and the interatomic bonds in martensite are therefore weaker than in α-iron.—V. G.

The Grain Boundary Energy, Its Measurement and Influence upon the Properties of Metals and Alloys. T. B. Massalski. (*J. B'ham. Met. Soc.*, 1952, **32,** June, 38–59). A short account of the existing theories of the nature of the grain-boundary structure precedes a description showing how the grain-boundary energy influences the varied spacial arrangement and distribution of phases in many alloys. Then follows a discussion of methods of calculating this energy, and some factors responsible for its variation. Finally, a recent theoretical attempt to calculate the intercrystallite energy is mentioned. (27 references).—P. M. C.

A Rational Theory of the Hardening of Steel. A. Marks. (Sheffield University, Dec., 1951). The pressure resulting from the quenching of a steel from above eutectoid temperatures is above the diamond graphite equilibrium and gives to the steel the hard character of diamond. The release of this pressure by tempering results in the deposition of fine colloidal graphite and ferrite, the former showing up dark on etching in acid. The martensite structure of a hardened steel shows traces of graphite in the characteristic triangular form of the tetrahedron, due to the quenching speed being too low to retain all the carbon in the diamond form. This theory also explains other phenomena observed in steels.—R. A. R.

Precipitation Hardening of Hot Working and High-Speed Steels. Kehsin Kuo. (*Research*, 1952, **5,** July, 339–340). The composition of the carbides in tungsten and molybdenum high-speed steels is discussed. The undissolved carbide found in quenched and tempered high-speed steels is usually given the formula M_6C. However, it has been found that the carbide which really contributes to the secondary hardening and red hardness of these steels is W_2C or Mo_2C. The effects of chromium, cobalt, and vanadium are outlined.—J. C. B.

Continuous Solid Solutions of Metals of the Transition Group of Mendeleev's Periodic System of Elements. I. I. Kornilov. (*Doklady Akademii Nauk S.S.S.R.*, 1950, **73,** 3, 495–497). The rule governing the ability of a given element to form solid solutions with iron and nickel is outlined and the extension of this rule to cover the formation of mutual solid solutions of other elements is discussed.—V. G.

The Iron/Iron-Phosphide/Aluminium-Phosphide/Aluminium Phase Diagram. R. Vogel and H. Klose. (*Arch. Eisenhüttenwesen*, 1952, **23,** July–Aug., 287–291). The iron corner of the Fe–Al–P phase diagram has been derived from thermal and metallographic investigations; and from the equilibrium conditions in the aluminium corner predicted from theoretical considerations. The phosphorus content of the ternary solid solution region decreases rapidly with aluminium content from 2·8% to 1·2% and then remains constant. There is no absolute difference in the affinities of aluminium and iron for phosphorus ; the ratio of the two metals determines whether the phosphorus is combined with aluminium or iron.—J. P.

The FeS–FeO–SiO_2 System. Ya. I. Ol'shanskii. (*Doklady Akademii Nauk S.S.S.R.*, 1950, **70,** 2, 245–248). On the basis of data from the available literature and additional experiments, the phase diagram of the ternary FeS–FeO–SiO_2 system is constructed.—V. G.

CORROSION

Galvanic Corrosion. E. C. Reichard. (*Chem. Eng. Prog.*, 1952, **48,** June, 269–271). The electrolytic corrosion method is explained, and the prevention of corrosion by paint, anodic coatings, insulation inhibitors, and cathodic protection is outlined. Some typical forms of sacrificial magnesium anodes are illustrated.—T. E. D.

Corrosion. M. G. Fontana. (*Indust. Eng. Chem.*, 1952, **44,** June, 81A–84A). Metals used for handling or processing caustic soda are liable to stress-corrosion, caustic embrittlement being an aspect of this. With unprotected steel, the significant factors are alkali concentration, temperature, stress, and time.—K. E. J.

Corrosion Testing. (*Mech. Eng.*, 1952, **74,** July, 581–584). Details are given of the corrosion testing facilities at the new marine testing station of the International Nickel Company at Harbor Island, U.S.A. These include a full-sized salt-water evaporator and distillation unit and apparatus for the study of the effect of marine foulings, and the protection of marine piling.—D. H.

Corrosion in the CO_2–H_2S–Amine System. E. O. Carlson, G. R. Davis, and K. L. Hujsak. (*Chem. Eng. Prog.*, 1952, **48,** July, 333–336). The corrosion of boiler tubes in the monoethanolamine-water treatment of natural gas, containing CO_2 and H_2S, was studied in a specially designed pilot plant, which is described. From the results, measures to prevent pitting of the tubes in production-scale plants are suggested.—T. E. D.

Preserving What You Have, from the Corrosion Engineer's Viewpoint. E. A. Tice. (*Chem. Eng. Prog.*, 1952, **48,** July, 329–332). A general discussion on corrosion deals with aeration or the presence of oxidizing agents, velocity of media flow or agitation effects, and temperature. The influence of these factors on corrosion rates of various metals was determined, and some simple precautions for decreasing these effects are mentioned.—T. E. D.

Method of Fixing and Insulating Specimens for Electrochemical and Corrosion Investigations. V. N. Modestova and N. D. Tomashov. (*Zavodskaya Laboratoriya*, 1950, No. 3, 365–366). [In Russian]. The use of polystyrene for sealing metal specimens into the solution-containing vessel during electrochemical and corrosion investigations is described.

The Prevention of Corrosion and Metal Attack in the Steam Water Cycle of the Steam Power Plant. F. G. Straub and H. D. Ongman. (*Corrosion*, 1951, **7,** Sept., 312–315). The potential sources of iron and copper solubility in the preboiler cycle and the effect of these metals on the steel in the boiler are examined. The results are given of studies conducted to determine the effect of the *p*H in the cycle on the solubility of these metals. The studies include the effect of increasing the *p*H of the steam and feed-water by means of the controlled addition of ammonia to the cycle. It is shown that by maintaining a *p*H of 9 in the feed-water with ammonia, the copper and iron solubilities are reduced to very low values. Methods of adding and controlling the ammonia are given. The action of reducing chemicals in the boiler beyond their normal action on free oxygen is discussed, with special reference to the reduction of iron and copper before these can enter the boiler as oxygen carriers.—J. F. S.

Corrosion Problems in Rural Power Distribution. O. W. Zastrow. (*Corrosion*, 1951, **7,** Sept., 308–311). Corrosion problems arising from electric power distribution in the rural districts are discussed. The galvanic corrosion of galvanized steel anchor rods underground is occasionally excessive. Atmospheric corrosion of pole fittings for overland lines is attributed to the use of galvanized steel in unsuitable conditions. Low alloy or stainless steels or bronze alloys could be used with advantage. The corrosion of steel pole-top pins is discussed.—J. F. S.

Corrosion Problems of Motor Coaches. K. L. Raymond. (*Corrosion*, 1951, **7,** Sept., 303–307). This is a survey of the corrosion problems encountered in the American motor-coach industry and of the methods used to minimize attack.—J. F. S.

Volatile Crystals Prevent Corrosion of Packaged Steel Parts. P. O'Keefe, jun. (*Mat. Methods*, 1951, **34**, Dec., 84–86). A new anti-rust compound, available in spray, dip, or powder form, is being marketed by the Shell Oil Co. The active substance, which is slightly volatile, is dicyclohexylammonium nitrate, designated 'VPI.' Protection can only be effected in enclosed spaces such as the interiors of aircraft engines. The properties of the compound and some of its many industrial applications are described.—P. M. C.

Dicyclohexylammonium Nitrite, a Volatile Inhibitor for Corrosion Preventive Packaging. A. Wachter, T. Skei, and N. Stillman. (*Corrosion*, 1951, **7**, Sept., 284–294). Dicyclohexylammonium nitrite inhibits the corrosion of steel in water. Being slightly volatile (vapour pressure $0{\cdot}1 \times 10^{-3}$ mm. Hg at 70° F.), it can also be used as a vapour-phase inhibitor. Its stability, volatilty, solubility, hardness, toxicity, and other properties are described. Results are given of corrosion prevention tests, mostly with wrapping paper impregnated with the compound. They include humidity tests on clean and on rusted steel, low-temperature tests, outdoor exposure tests, and tests in the presence of oil. In the vapour phase, deleterious effects occurred with only a few substances. Duration of protection depends on initial concentration of inhibitor and adequate sealing to prevent losses. Indoors with 1 g. of inhibitor per sq. ft. of wrapper, corrosion of steel in simple packages is inhibited for one to three years.

Stress Corrosion Cracking in Alkaline Solutions. Sub-Surface Corrosion by Alkaline Solutions. H. W. Schmidt, P. J. Gegner, G. Heinemann, C. F. Pogacar, and E. H. Wyche. (*Corrosion*, 1951, **7**, Sept. 295–302). Data, obtained from an American industrial survey to determine the conditions under which stress-corrosion cracking in alkaline solutions (caustic embrittlement) occurs, are presented. Most of the data refer to sodium hydroxide. Four theories to account for attack are discussed. Only an approximate relationship of temperature and concentration to cause failure is found. Corrective measures that have been employed are discussed.—J. F. S.

The Influence of Supersonic Vibrations on the Solution of Steel in Sulphuric Acid. A. P. Kapustin and M. A. Fomina. (*Doklady Akademii Nauk S.S.S.R.*, 1952, **83**, 6, 847–849). [In Russian]. Supersonic vibrations of low intensity have no influence on the rate of solution, but with increasing intensity this rate quickly increases.—V. G.

ANALYSIS

Spectrophotometry in Analytical Chemistry. E. Geffroy. (*Chim. Analy.*, 1952, **34**, June, 119–125). The essential qualities of accurate spectrophotometry are outlined, and a method of determining vanadium and titanium colorimetrically is described. The main features in the construction of the equipment necessary, and the possibilities of the method are mentioned. The infra-red spectrophotometer and the double monochromator are explained.—T. E. D.

Modern Spectrochemical Analysis: Application in Iron and Steel Industry. J. Rose. (*Iron Coal Trades Rev.*, 1952, **165**, Aug. 22, 407–412). The author reviews the development of spectrography from early days, and discusses recent advances in this field, particularly in the application of spectrography to process control of steelmaking and to the analysis of slags and non-metallic constituents. Present-day techniques are described and the advantages of this method of analysis are given.—G. F.

Two-Line-Pair Nomograph for Non-Parallel Working Curves in Spectrographic Evaluation. J. L. Flounders. (*J. Appl. Chem.*, 1952, **2**, June, 295–296). Nomographic evaluation of the two-line-pair method of spectrographic analysis is extended by a simple geometric construction to include non-parallel working curves such as are obtained when a neutral filter is not used.—E. C. S.

A Semi-Automatic Graphical Computer with Use in Spectroscopy. G. L. Weissler, A. W. Einarsson, and J. D. McClelland. (*Rev. Sci. Instruments*, 1952, **23**, May, 209–212). The design of an improved form of Beals' intensitometer is described, which is capable of transforming semi-automatically, a microphotometer density *versus* wavelength trace into an intensity trace. A detailed example presents successive evaluations of the quantities in Lambert's law $I = I_0 \exp(-Kx)$ plotted against wavelength.—H. D. W.

The Technique of Servo Control Applied to the Design of an Automatic Spectrophotometer. G. G. Sutton. (*Trans. Soc. Instrument Techn.*, 1951, **3**, Dec., 157–166). The fundamentals of spectrophotometry are discussed and the design of a special instrument is described. The spectrophotometer is entirely automatic and measures, by means of a chopped light and photo-multiplier system, the difference in transmission between two light paths, one containing solvent plus solute and the other solvent only. These two liquids are contained in separate cells and a servo adjusts the optical length until the two signals are equal. This is a null method of measurement, and the same photomultiplier is used for composing both signals. The advantage of this device lies in the great saving of time in plotting absorption curves.—H.D.W.

Direct Reading Spectrograph. (*Metal Ind.*, 1952, **80**, June **13**, 485, 486). The instrument, of French design and manufacture by Companie Radio Cinema, is the first of its kind in this country, and is installed at the London works of John Dale Ltd. The reading head, which is entirely automatic, houses two cæsium–antimony photocells of the electron multiplier type, one receiving the ultra-violet radiation from the standard line, the other receiving the radiations from the specimen at selected wavelengths for the elements being determined. A pen recorder gives the analysis for seven elements in 2½ min., and ten elements (which require a second programme ruler) in 4 min.—P. M. C.

Spectrographic Determination of Alloying Elements in Steel. W. Klimecki and Z. Makarucha. (*Prace Instytutu Metalurgii*, 1952, **4**, 2, 127–143). [In Polish]. Methods for the quantitative spectrographic determination of manganese, silicon, chromium, nickel, molybdenum, and vanadium in steel are described.—V. G.

The Determination of Iron by the Iodometric Method. L. J. White. (*Coke Gas*, 1952, **14**, Aug., 285–288). The various modifications of the method are reviewed and recent work is described. The exact effects of excess KI and dilution have been determined and conditions have been established which give a high accuracy. The proposed modifications to the method are fully described.—T. E. D.

HISTORICAL

Some Notes on the Early Days of the Manufacture of Railway Tyres in Great Britain. G. Baker. (*J. Jun. Inst. Eng.*, 1952, **62**, Part 9, June, 293–304). This is a brief history of the development of railway tyres from about 1600 through the cast-iron wheel tyre and the welded ring to the continuous forged tyre of the present day.—J. C. B.

An 18th Century Bloomery at Garstang, Lancs. H. R. Schubert. (*J. Iron Steel Inst.*, 1953, **173**, Jan., 30). [This issue].

Creators of the Steel Age—V: Isaac Lowthian Bell, F.R.S. R. Edwards. (*Brit. Steelmaker*, 1952, **18**, Aug., 408–412). This article describes the career of Isaac Lowthian Bell, the most outstanding figure of the British iron industry in the 19th century. He contributed in no uncertain way to the age of steel by being the first practical ironmaster to show how the manufacture of iron and steel, by the application of scientific methods and particularly of chemical analysis, could become a precise scientific operation.—G. F.

Floris Osmond—A Pioneer in Physical Metallurgy. E. N. Simons. (*Metallurgia*, 1952, **45**, June, 281–282). A brief outline is given of the work of Floris Osmond (1849–1912), with special reference to the allotropic theory of hardening.

Metallurgical Techniques Applied to Archeology. A. France-Lanord. (*Rev. Mét.*, 1952, **49**, June, 411–422). Metallurgical interest centres on (*a*) the study of the historical evolution of techniques, and (*b*) the restoration of metallic antiquities. A study on the fabrication of Damascene swords is described and an account of the corrosion and preservation of ancient bronzes given.—A. G.

Fifty Years of Vereeniging and the Birth of the Steel Industry in the Town. (*USCO Mag.*, 1952, **3**, July, 7–11). The establishment of Vereeniging may be said to date from 1878 with the discovery of coal in the district. Its history and growth are traced. Industries include the USCO steelworks, production of electric power, and coalmining.—J. C. B.

USCO Celebrates Its 40th Anniversary. (*USCO Mag.*, 1952, **3**, July, 13–21). A brief history of the South African steel industry is given with major emphasis on the USCO plant at Vereeniging founded in 1912.—J. C. B.

The History of Pig Iron Manufacture in Alabama. B. C. Colcord. (*Amer. Iron Steel Inst. Regional Tech. Meetings*, 1950, 107–119). The development of the pig-iron industry in Alabama is reviewed. The early handicaps encountered are described, and the effects of the civil war era are examined.

ECONOMICS AND STATISTICS

The Prospects for American Industry. B. Moreell. (*Amer. Iron Steel Inst. Regional Tech. Meetings*, 1950, 1–14). The author discusses the growth of America industry, with particular reference to the iron and steel industry, and outlines the factors which have made it possible for America to produce over one-third of the world's goods. A comparison with British industry is made.—G. F.

Steel for the Expanding Industry of California. A. G. Roach. (*Amer. Iron Steel Inst. Regional Tech. Meetings*, 1950, 121–132). The author outlines the development of California's industrial economy and shows the part played in this development by the steel industry.—G. F.

The Pacific Northwest and Its Potentialities. H. H. Fuller. (*Amer. Iron Steel Inst. Regional Tech. Meetings*, 1950, 133–139). The author considers the natural resources and production of the States of Oregon, Washington, Idaho, and Montana. He concludes that increasing industrialization within the area is inevitable, and that its potentialities are almost unlimited.—G. F.

Steel for Western Needs. J. R. Zadra. (*Amer. Iron Steel Inst. Regional Tech. Meetings*, 1950, 151–158). The origin and early history of the steel industry in Western U.S.A. are examined, and the industry's development through the years to meet the needs of other expanding industries is discussed.

The European Steel Situation. C. B. Randall. (*Amer. Iron Steel Inst. Regional Tech. Meetings*, 1950, 175–183). The author discusses the present situation of the European steel industry. The raw materials and scrap position is considered, and the probable effects of the Schuman plan are outlined.

A Canadian Integrated Coal and Steel Industry. L. A. Forsyth. (*Canad. Min. Met. Bull.*, 1952, **45,** May 262–263: *Trans. Canad. Inst. Min. Met.*, 1952, **55,** 172–173). The distribution of raw materials, steelplant, and markets for the finished products in Canada are discussed with special reference to the Dominion Steel and Coal Corp., Ltd. Unfortunately, where the raw materials are so located as to create advantage in production, the advantage is lost by the distance from places where the product can be marketed.—T. E. D.

The Past, Present, and Future of the Canadian Steel Industry. J. Convey and S. L. Gertsman. (*Canad. Min. Met. Bull.*, 1952, **45,** May, 271–274: *Trans. Canad. Inst. Min. Met.*, 1952, **55,** 181–184). A general survey is made of the remarkable development of Canadian steel production, from the earliest blast-furnace in 1800, to the present production of over three million tons of steel per annum. The possibility of the use of electric smelting in Western Canada is suggested, and the spread of production to new areas is foreseen in the future.—T. E. D.

MISCELLANEOUS

Radioactive Isotopes in Ferrous Metallurgy. C. M. Parker. (*Amer. Iron Steel Inst. Regional Tech. Meetings*, 1951, 297–306). After outlining what is meant by a radioactive isotope, discussing their principle radiations and their rates of decay, the author gives details of studies in ferrous metallurgy, in which they have been used. These include studies of the physical chemistry of steelmaking, and mechanical uses such as the determination of the thickness of pipe walls.—G. F.

Methods of Producing Radioiron. R. W. Dunn. (*Nucleonics*, 1952, **10,** July, 8–13). Data are given on the yields and specific activities of samples of Fe^{55} from manganese, and Fe^{59} from cobalt produced in the 60-in. Berkeley cyclotron; samples of Fe^{59} from copper in the 184-in. Berkeley cyclotron are also discussed.—H. D. W.

Radioactive Isotopes: Their Properties and Uses in the Steel Industry. G. Oldham. (*Brit. Steelmaker*, 1952, **18,** Sept., 460–467). The author first deals briefly with the general properties of natural radioactive elements, the detection of radioactivity, and the discovery and development of artificial radioactive isotopes. He then describes specific applications where isotopes have been of service to the iron and steel industry; these include the determination of gas velocity, refractory wear and burden transit times in the blast-furnace, and the study of segregation in steel.—G. F.

Use of Radioactive Elements in Research, Particularly in Research on Metallurgical Materials. O. Hajiček. (*Hutnické Listy*, 1952, **7,** 6, 295–298; 7, 351–356). [In Czech]. The production and properties of radioactive isotopes suitable for metallurgical research purposes are described, and some applications are discussed.—P. F.

Radioactive Isotopes and Some of Their Properties of Importance in Metallurgy. V. Petržilka. (*Hutnické Listy*, 1952, **7,** 6, 285–290). [In Czech]. This is a review of the fundamental physical aspects of radioactivity, including its measurement. A table of the most important isotopes applicable in metallurgy is given, together with data as to the type of decay, energy of the radiation, half-life, and the form in which the isotopes are generally and conveniently handled in practice.

The Visual Presentation of Instrument Data. K. F. H. Murrell. (*Trans. Soc. Instrument Techn.*, 1952, **4,** Mar., 1–8). The major findings of recent research are summarized and evidence is supplied for the suggested design of scales. Consideration is given to the displays which fall into the main groups of use in conjunction with controls, and those for pure indication. The practical relationship of dial size, graduation system, interpolation, and reading distance is discussed and examples of scalemarkings are given.—H. D. W.

New American Scientific Equipment: Instruments Received by British Metallurgical, Engineering, and Coal Research Laboratories. (*Iron Coal Trades Rev.*, 1952, **165,** Aug. 22, 423–426). A review is given of a number of American scientific instruments supplied to British research laboratories since the war. These include production-control quantometers, high-temperature dilatometer, Yukon microhardness tester, portable profilometer, and Hyd-Robot automatic low-temperature fractional analysis apparatus.—G. F.

Railway Traffic at the Appleby-Frodingham Steelworks. E. R. S. Watkin. (*J. Iron Steel Inst.*, 1953, **173,** Jan., 1–15). [This issue].

Pneumatic Measuring and Control Systems. J. R. Fawcett. (*Mech. World*, 1952, **131,** June, 246–251). A practical review is presented of a very sensitive method of taking measurements, and, in conjunction with relays and power elements, of exercising control and telemetering functions.—D. H.

Course in Industrial Instrument Technology. I—Basic Elements or Mechanisms. II—Diaphragms. III—U-Tube Manometers. IV, V—Flow Metering Elements for Fluids in Pipes. VI—Measuring Instruments for Differential Flow Elements. VII—Flow Measurement: Integration from Differential Pressure Instruments. VIII—Area Meters: Rotameters and Flowrators. IX—Anemometers, Electrical Flow Meters, and Quantity Meters. X—Electrical Methods. XI—Electrical Methods: Resistance Thermometers. XII—Radiation Temperature Measuring Instruments. XIII—Humidity Measurement. XIV—Industrial Electronic Instruments for the Measurement (and Control) of Temperature, Pressure, Flow, etc. XV—Electronic Instruments. XVI, XVII, XVIII—Automatic Control. J. T. Miller. (*Instrument Practice*, 1951, **5,** Feb., 201–212; Mar., 269–275; Apr., 335–340; May, 418–423; June, 497–502; July, 575–580, 585; Aug. 682–687; Sept., 738–743; Oct., 811–817; **6,** Nov., 30–36; Dec., 102–108; 1952, Jan., 167–171; Mar., 314–318; Apr., 388–394; May, 471–478; June, 534–543; July, 606–624; Aug., 692–700).

Modern Quality Controls Are Simple to Use. H. F. Myers. (*Iron Age*, 1952, **169,** May 1, 144–146). The elements of quality control charts are described and it is shown how they can indicate quality levels and impending troubles. They can also be used to give a factual basis for establishing or altering specifications.—A. M. F.

New Million Dollar Liquid Oxygen/Nitrogen Plant. J. F. Brinley. (*Welding J.*, 1952, **31,** June, 495–499). A description is given of the production of pure oxygen, nitrogen, and argon by the Houston Oxygen Co. in the U.S.A.—U. E.

Dispersion from Short Stacks. C. A. Gosline. (*Chem. Eng. Prog.*, 1952, **48,** Apr., 165–172). Theories of dispersion from stacks are surveyed, including those of Bosanquet, Sutton, and Church. The effect of stack height on the time/average-concentration curve is shown and methods of measurement are explained. Results are compared with calculated values.—T. E. D.

Control and Recovery of Dust and Fume in Industry. R. Ashman. (*Inst. Heating Eng.*, 1952, **14,** June, 163–166; July, 212–215, 217). Methods of dust control for dusts of various sizes are surveyed. The design of hoods and the effect of velocities in ducts are mentioned. The operation of cyclones, electrostatic precipitators, sleeve filters, and ultrasonic recovery filters is explained.—T. E. D.

BRITISH ELECTRICAL DEVELOPMENT ASSOCIATION. "*Materials Handling in Industry.*" (Electricity and Productivity Series, No. 4). 8vo, pp. xvii + 142. Illustrated. London [1952] : The Association. (Price 8*s.* 6*d.*)

It is apparent that in many industries there is at least as much scope for increasing productivity by attention to the handling and moving of materials between the various processes as by improvements in the processes themselves, for, as the author says, "Every time a material is handled, something is added to its cost and nothing to its value." Although the first object should always to be eliminate unnecessary handling by care in the layout and integration of the sequence of processes, there inevitably remains a minimum amount of handling of the raw materials, the products during manufacture, and the tools and supplies necessary for the processing. Much of this handling can be mechanized with advantage, and this book sets out to review the different types of equipment available for the handling of materials in order to assist in the correct choice for any particular purpose. Its scope is limited to handling within and around buildings and it does not, in general, deal with the needs of heavy industry.

Since the book is addressed primarily to those responsible for selecting equipment, it deals only broadly with each type, for, once the right type of machine has been selected, details are always available from manufacturers and other users. An attempt is made, however, to include sufficient description of points of construction to show the main limitations and advantages of the various types of machine. Each description is divided into two sections, the first dealing with the field of use of the equipment, and the second with its main distinguishing details of construction.

After a general discussion in the early chapters on mechanical handling and general rules for the choice and application of equipment, the subject is dealt with according to the following classification : Overhead runways and lifting equipment ; cranes ; chain conveyors (and allied types) ; elevators ; roller, belt, slat, and other conveyors ; floor transport and storage ; vibrators ; and miscellaneous equipment. A few brief case histories, lists of equipment suitable for handling individual articles and for bulk handling, and a list of relevant British Standards complete the book.

It is well indexed and freely illustrated with photographs or drawings, and the latter are very clear and not burdened with superfluous detail. In a few places, however, notably in the chapter on elevators, the reader, who must be presumed to have little prior knowledge of the subject, may have difficulty in visualizing from the brief descriptions those types for which no illustrations are provided.—H. R. MILLS

CORDS, ERICH. "*Die Technische Entwicklung des Peiner Walzwerks*, 1872–1950." 8vo, pp. 116. Illustrated. Düsseldorf, 1952 : Verlag Stahleisen m.b.H. (Price DM 8.–)

This is an historical account of the rolling mills in Peine, near Ilsede, Germany, from their inception in April, 1872, to the present time. Whilst reference is made to business and commercial activities, the account is principally concerned with the technical side. In the first year the production was less than 3000 metric tons, in 1939 it exceeded half a million ; the total tonnage rolled over a span of more than 75 years exceeds 17 million metric tons. The scale of technical development in this period is reflected in the fivefold increase of output per man. The story is told chronologically and is amply documented by statistics.—J. G. WISTREICH

FREEMAN, H. G. "*Fachwörterbuch Werkzeuge.*" Part II. "English–German." Sm. 8vo, pp. 390. Essen, 1952 : Verlag W. Girardet. (Price DM 24.–).

Part I of this dictionary of tools has already been reviewed in the August, 1951, issue of this *Journal* (vol. 168, p. 447).

In Part II, as in the German–English part, a number of words and phrases from the allied fields of materials and their treatment, and of manufacturing processes, have been included, in addition to hand and machine tools, and measuring instruments which form the real subjects of the dictionary. The British user must remember that the dictionary is essentially as American–German one ; but where the English spelling differs from the standard American the English word is entered in its alphabetical place and cross-referenced to the American, compound words and phrases only being found in the latter place. In the same way, where names of tools in common use in the two countries differ completely, both names are generally entered, although the apparent omission of a few common English words may well be due to their not being in such common use in America—for example, the German equivalent of 'tommy bar' will only be found by looking up 'pin handle,' and of 'swarf' by looking up 'turnings.' So long as this limitation is borne in mind, the dictionary will be very useful to anyone needing the German equivalents of tool names, a large number of compound names being included which are not readily found in more general technical dictionaries.

Factors and tables for conversion between metric and English or American units are also given. The list of abbreviations used in the dictionary is incomplete, but it is unlikely that any difficulty will be found in guessing their meaning.—H. R. MILLS

"*Kingzett's Chemical Encyclopedia.*" Edited by R. K. Strong. 8th Edition. La. 8vo, pp. xii + 1186. London, 1952 : Baillière, Tindall and Cox. (Price 70*s.*)

The fourth edition of "Kingzett" contained 807 pages, the sixth 1088, the seventh 1092 ; it can be seen that this "epitomized digest of chemistry and its industrial applications," as its original compiler called it in 1924, continues to grow in size and scope. It remains a valuable, possibly an indispensable, volume for the chemist, but the metallurgist, though he will find it supplements his chemical knowledge, will scarcely be able to recommend the metallurgical entries to the chemist, or use them to advance his own knowledge. Serious errors were noted in earlier editions, and some have been corrected ; unfortunately not all. There still remains a list of alloys of which nearly half are incorrect—the outstanding mistake being the attribution to aluminium bronze of a composition of 9 parts of copper to one of zinc. On the ferrous side there is, to say the least, a contradiction between the two statements (i) that "the greater bulk of steel now produced in the world is made by the so-called 'Thomas-Gilchrist' process" and (ii) that "about 70% of the steel produced in the United Kingdom is made by the open-hearth process, and in the United States this percentage is over 90." Moreover, it is not wholly true that "so-called mild steel contains from 0·1 up to about 0·4% of carbon, hardening being effected by the addition of carbon to the outer layers" ; many such remarks suggest that the contributor and the editor are not metallurgists themselves, and have relied on commercial rather than on technical literature. It should be noted, however, that to many entries a reasonably good bibliography is attached—and that this seldom contains entries later than 1944. It would be unfair to condemn this book outright on the study of what is, after all, a very small portion of its contents, but it is certainly of little value to metallurgists.—J. P. S.

SCHWARTZ, ADOLPH. "*Was der Mann aus der Schmiede von seiner Arbeit wissen muss!*" (Stahleisen Schriften, H.4). 8vo, pp. 126. Illustrated. Düsseldorf, 1952 : Verlag Stahleisen m.b.H. (Price DM 7.20)

This is an educational booklet for the craftsman. The job of telling the layman or the apprentice about forging could not possibly be done more briefly, more effectively, and more engagingly. Admittedly a craft cannot be learnt from a book, but there is always a good deal that is worth knowing about it before starting one's training. The booklet will also be read with keen enjoyment, and surely also with benefit, by the skilled hand, by the forgemaster, and indeed by anyone proficient in some branch of the forging industry. On each page the author manages to give an apt and pithy definition of his topic, to convey details with the help of well-chosen photographs and his own expert and artistic sketches (there are 276 illustrations on 120 pages of text), and to slip in practical hints in the form of slogans which are found to stick in one's memory once and for all.

The topics are : Forgings, forging operations, steel, heat-treatment and forging temperature, heating plant, tools and forging, 'ten commandments' for the press and hammer foreman, for the furnaceman and crane driver, and hints on hygiene and safety. The author has even found room for a glossary of forge jargon and technical terms, and for a few well-chosen words on costs, prices, and

profits, and the need for the prevention of scrap, waste, and damage to equipment. The description covers both smithy and heavy forge ; drop forging is left out. The information is up-to-date.

The reviewer has only one regret—that the book is in German and therefore inaccessible to most apprentices in this country. May this drawback be repaired as soon as possible.—J. G. WISTREICH

NEW PUBLICATIONS

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS. "*Industrial Ventilation.*" La. 8vo, loose-leaf. Pp. 163. Illustrated. Michigan, U.S.A., 1951 : The Conference. (Price $3)

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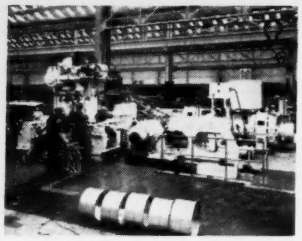

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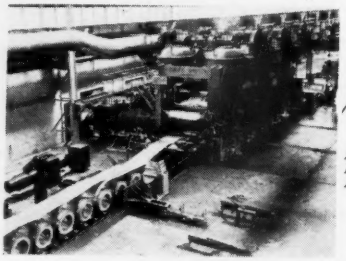

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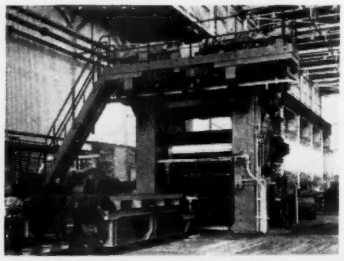

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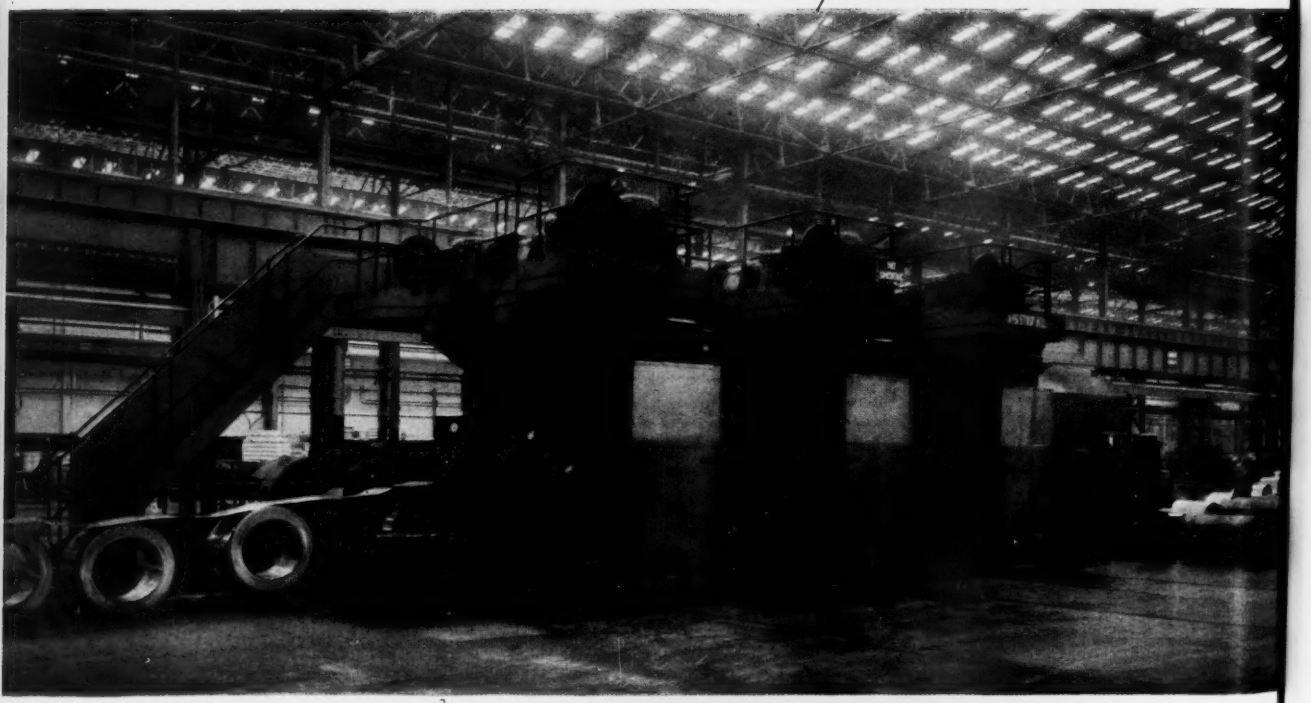

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E. TAYLOR-AUSTIN, F.R.I.C., F.I.M.

EDWARD TAYLOR-AUSTIN was born in Birmingham in 1909. He was educated at King Edward's Grammar School, Aston, Birmingham, and at Birmingham Central Technical College.

From 1926 to 1929 he was an indentured apprentice to a firm of metallurgical analysts; at the conclusion of his apprenticeship he was appointed Assistant Chemist to the British Cast Iron Research Association, and in 1933 he became Chief Chemist. His work involved a considerable amount of research and he has been responsible for a number of published papers and reports.

Subsequent posts held were : Assistant Blast-Furnace Manager to the Darwen and Mostyn Iron Co., Ltd., Mostyn (1941-1943); Works Manager and Chief Metallurgist of the Ministry of Supply's factory at Llanerch-y-mor, Holywell (1943-1951) and, since 1951, when the factory was relinquished by the Ministry of Supply, of the Darwen and Mostyn Iron Co., Ltd.

Since 1941 he has directed his attention to research in extraction metallurgy; this has involved the development of a new continuous aluminothermic process for the commercial production of some 20 grades of refined ferro-manganese.

For some years Mr. Taylor-Austin has been a part-time Lecturer in advanced metallurgical and chemical subjects : at the Wednesbury Technical College from 1938 to 1941, and at the Deeside Technical College since 1947.

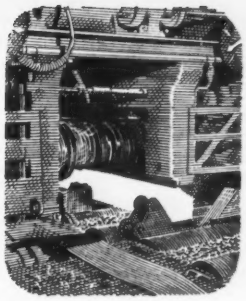
From 1938 to 1941 Mr. Taylor-Austin was a member of the Oxygen Sub-Committee of the Heterogeneity of Steel Ingots Committee of The Iron and Steel Institute, for which he carried out investigations on oxides and inclusions. He has served on the Blast Furnace Materials Analysis Sub-Committee of the British Iron and Steel Federation since 1939. He is a Fellow of the Royal Institute of Chemistry and a Member of the Council of the North Wales Section, a Member of the Society of Public Analysts, and a Fellow of the Institution of Metallurgists. He is a Founder Member of the North Wales Metallurgical Society and was appointed Chairman in 1951. He became a Member of The Iron and Steel Institute in 1941.

E. Taylor-Austin, F.R.I.C., F.I.M.

Honorary Member of Council, 1952-53

Developments in the Rolling of Broad Flange Beams

AT THE CARGO FLEET IRON COMPANY LTD.



By G. Barry Thomas

SYNOPSIS

The initial trials by which broad flange beams have become a standard product in a conventional 2-high cross-country mill are described. Details of roll design, the method of working both in the cogging mill and in the finishing mill, and the construction of the vertical roll housings to produce a beam with parallel flanges are given. 721

In the years between the two Wars, numerous schemes for the production of broad flange beams at Cargo Fleet were visualized, some reaching the designing stages. At that period it was envisaged that the only practical method of production was by the Grey-type mill, and that this mill would have to be placed in line with the existing 32-in. section mill and driven by the finishing vertical steam engine from its tail end. When this engine was installed, shortly after the first World War, it had a coupling at each end of the crankshaft, so that it could be used to drive another train of rolls by simply uncoupling the box from the wobbler end of the bottom pinion at the pinion housing, which drives the finishing end of the 32-in. mill.

None of the ideas that were investigated was satisfactory from all points of view. The greatest problem was the ability to install sufficient cooling-bank area without adversely affecting the existing section and rail-cooling banks.

With the intervention of the War, the schemes were postponed. However, a 10 in. × 10 in. joist had already been successfully produced in the 32-in. mill, and the rolls for a 12 in. × 12 in. section were being cut.

EARLY TRIALS IN THE 32-IN. MILL

The 10 in. × 10 in. Section

Design—In early 1945 a design was prepared for rolling 10 in. × 10 in. beams with parallel flanges in the 32-in. mill. This mill has four stands with a screwdown at the first position. The roll barrel is 6 ft. 0½ in. long and has roll necks of 18½ in. dia. The bar had to be formed in the first three stands, as the fourth was entirely taken for the vertical roll housings.

Turning of Rolls—When the design was completed in the autumn of 1945, the turning of the four pairs of rolls began. It was considered essential to have a bloom height of 16 in. to enter the first forming hole; otherwise the 10-in. flange length in the finished bar would not be obtained. This height was impossible to achieve, as the window in the bloom shears would only just admit 15⅜ in., or 15½ in. with safety, even after the smallest possible shear blade had been fitted to the top apron. The bloom was eventually sheared on its 'flat,' and charged on its 'flat' into the reheater, without the difficulties at first anticipated.

Trial Run—The turning of the rolls was completed early in February 1946: each pair was mounted in the stands, and the necessary top guides, flange guides, and horns were fitted. It took only a short time for the rolls to be built up, the mill to be changed, and all necessary adjustments to be made. The bloom, which was 15½ in. × 7⅛ in. × 15 ft. (approx.) long, was drawn from the wash-heating furnace and delivered into the mill.

Results—The results of this trial were most satisfactory, and the dimensions of the bar produced were almost identical with those of the required standard. It had been proved that there was no difficulty in achieving a 10 in. flange with a bloom of at least ½ in. less in height than the 16 in. that had been considered to be a minimum.

The 12 in. × 12 in. Section

As the mill is only 32-in. centres, there was a risk that premature failure of the rolls would occur when they were cut to the depth necessary for the 12-in. flange. The roll diameters were therefore increased to the maximum that the housings would hold (*i.e.*, 35½-in. centres of rolls), and forged steel rolls of 0·45–0·50% C and 0·75–0·85% Mn were used. These types of roll had previously given excellent results in the rolling of the heavier joists and sections, and there was every confidence that they would prove satisfactory on this occasion. They are hard and have good wearing qualities without being brittle, and can therefore stand shocks that might cause other qualities to fail. Machined plates 1½–2 in. thick were placed under the housing feet to raise the level of the rolls for satisfactory delivery on to the tables.

There was also a problem concerning the hot saw. As the saw travelled through the bar, its 'boss' just cleared the 10-in. beam flange; therefore it would obviously foul a 12-in. flange. To overcome this, the saw guide rails were lifted 3 inches and the saw

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Mr. Thomas is Director and General Works Manager of the Cargo Fleet Iron Company Ltd., Middlesbrough.

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diameter was increased from 51 in. to 54 in. This saw, which is of a fairly heavy horizontal type, twin-belt driven, and with a hydraulic feed, has proved to be most satisfactory, even when cutting the largest beams.

It would not have been possible to produce the 12 in. × 12 in. section in the 32-in. mill without a formed bloom from the cogging mill, as the roll barrel length was insufficient. A cogging roll was therefore designed to give the required formed bloom, and also to produce any standard-size bloom needed for rail and section rolling. This was done in the 8 ft. 6 in. barrel length.

The 14 in. × 12 in. Section

By increasing the upward range of the beams, the forming hole was designed to suit the production of a 14 in. × 12 in. section. Before these rolls were turned, a forming hole that would enable the 32-in. mill to be fed with a formed bloom for producing 16-in. and 18-in. sections was squeezed in. This was one of the few failures at first encountered: the top roll, weakened by the very deep cutting for the four flanges, broke very early, before any 18-in. beams had been rolled. The original design of one forming hole only was then used, and has proved to be satisfactory.

Figures 1*a* and *b* show the cogging rolls and forming holes for the production of 12 in. × 12 in. and 14 in. × 12 in. beams, as they are today, the flange length being 15½ in. and the web thickness 4 in. This is termed a general cogging, and it is used to produce all sizes of square and rectangular blooms for general sectional and rail work, thus avoiding roll changing in production periods.

In the second hole (which is 20 in. wide), there is an appreciable 'belly.' This ensures that the side of the bloom is sufficiently concave to avoid shearing on the collars of the forming hole. Normally, four passes are given in the forming hole; the bloom is then turned on to its side and given two passes in the 20-in. hole, to take off the side that has formed; it is finished with another three passes in the forming hole.

When rolling was begun, the web thickness of the formed bloom was 2 in., the height 15½ in., and the wt./ft. of the bloom about 330 lb. The maximum length that could be taken into the wash-heater was 19 ft. 6 in., so that, on the required 90% yield from bloom to finished bar, the finished lengths of beam were about 70 ft. of the 12 in. × 12 in. section and 58 ft. of the 14 in. × 12 in. section.

Method for Producing Abnormal Finished Lengths—The 12 in. × 12 in. section was sufficiently long to cover all practical requirements of the structural engineer, but there was some demand for longer lengths in the 14-in. section. A longer bloom was therefore made and charged slightly crosswise into the furnace; but this process was slow and it reduced the number of blooms that the furnace normally holds. The weight of the bloom was then increased by finishing rolling with the rolls 2 in. apart. This thickened the web to 4 in. instead of the 2 in. thickness that was then standard. As the flange length was thus increased by 2 in., the bloom was unable to pass through the shears. Shearing on the flat was attempted, but the flanges were so badly squeezed together that the bar would not enter the first forming hole in the finishing mill. With two light passes, this extra 2 in. was then rolled off the flanges in the slabbing hole. There was no distortion of the bloom.

At the first hole in the first-position screwdown stand of the 32-in. mill, the bar was given two extra passes and successfully worked through the train, giving an extra six feet of 14 in. × 12 in. beams and eight feet of 12 in. × 12 in. beams. This method was used on all formed bloom sizes when abnormal finished lengths were required. Since then the rolls have been cut as shown in Fig. 1*b*, making 4 in. the standard web thickness and the flange length 15½ in., and raising the bloom weight to 360 lb./ft.

The 24 in. × 12 in. Section

A design was then made for producing a 24 in. × 12 in. beam, and it was planned to produce beams from 6 in. to 24 in., in sizes increasing in width by 2 in. The 22 in. × 12 in. beam was incorporated in the 24-in.-beam cogging design, and, as the bloom width precluded the possibility of turning this set of rolls into a general pair, they were turned with robust collars, to avoid any danger of failure (Figs. 1*c* and *d*).

The 16 in. × 12 in., 18 in. × 12 in., and 20 in. × 12 in. Sections

Figures 1*e* and *f* show a pair of rolls that were turned to give a bloom for the 18-in. and 20-in. beams similar to that for the 22-in. and 24-in. pair. Again, this is a special pair for these two sizes only.

There was still the problem of producing a bloom for the 16 in. × 12 in. size, without, if possible, going to the expense of cutting another pair of cogging rolls, and involving another cogging roll change, for this one size only.

When the 18-in. and 20-in. cogging rolls were mounted, one of the formed blooms was turned on its side and passed through the slabbing hole with a 3-in. draft; when the bloom was cold, slices were cold-sawn from the top, middle, and bottom. These were found to be free from distortion, and the profile matched up satisfactorily with the first forming hole in the finishing-mill design. Since then, all the 16-in. beams have been produced by this method.

Thus it is possible to produce a complete range of coggings to roll all beam sizes from 6 in. × 6 in. up to 24 in. × 12 in. Beams up to and including 10 in. × 10 in. are rolled from square or rectangular blooms. After the 10 in. × 10 in. size, a general cogging with a formed hole is inserted to give 12 in. × 12 in. and 14 in. × 12 in. sections. There are two more beam coggings: one to give 16 in. × 12 in., 18 in. × 12 in., and 20 in. × 12 in. beams, and the other to give 22 in. × 12 in. and 24 in. × 12 in. beams. Cogging rolls can be changed in 1¼–1½ hr., so that very little production time is lost when changing over from beams to sections and piling, or from beams to rails.

GENERAL RECONSTRUCTION OF THE COGGING MILL IN 1948

The cogging mill was rebuilt in 1948. Apart from the manipulators and part of the ingoing and outgoing roller gear, everything was entirely replaced. The mill is driven by a 4850-h.p., 54–140-r.p.m., 625-V.

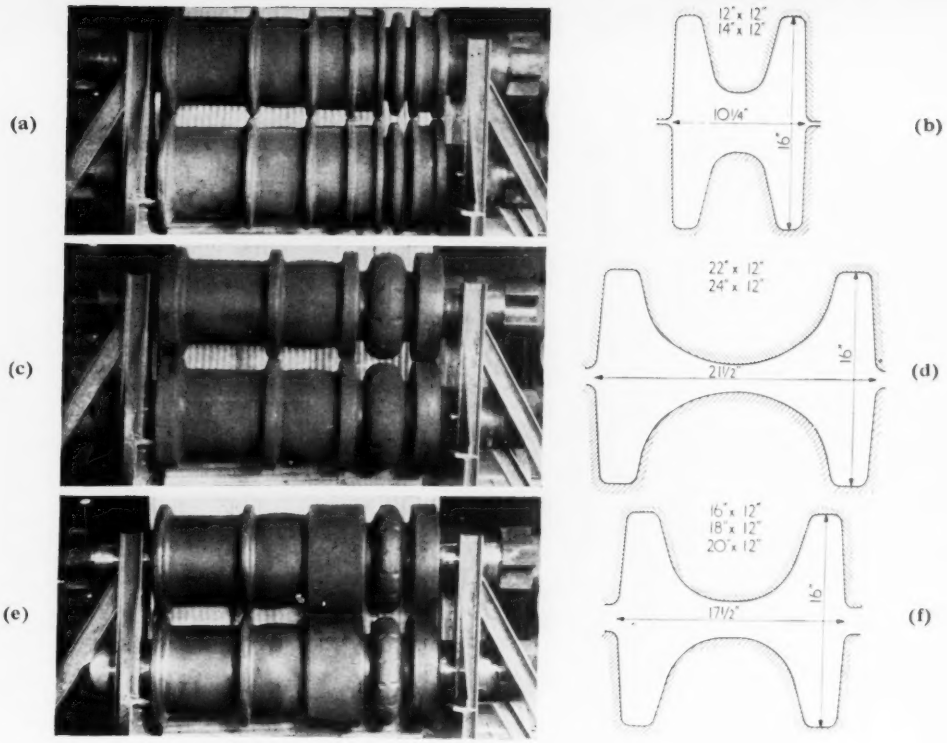


Fig. 1—Cogging rolls and forming holes for: (*a*) and (*b*) 12 in. × 12 in. and 14 in. × 12 in. sections; (*c*) and (*d*) 22 in. × 12 in. and 24 in. × 12 in. sections; (*e*) and (*f*) 16 in. × 12 in., 18 in. × 12 in. and 20 in. × 12 in. sections

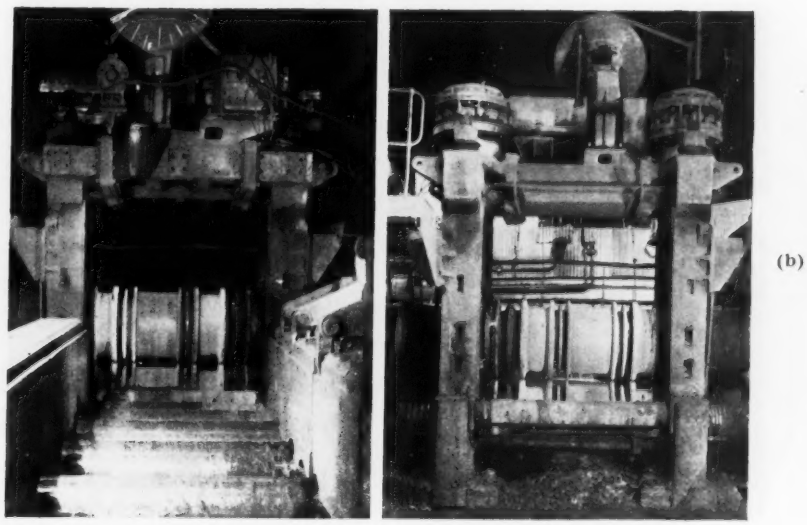


Fig. 2—First-position rolls for 6 in. × 6 in., 7 in. × 7 in. and 8 in. × 8 in. beams: (*a*) front view, showing fixed entry table and ruler manipulators; (*b*) back view

[*Barry Thomas*
[*To face p.* 114

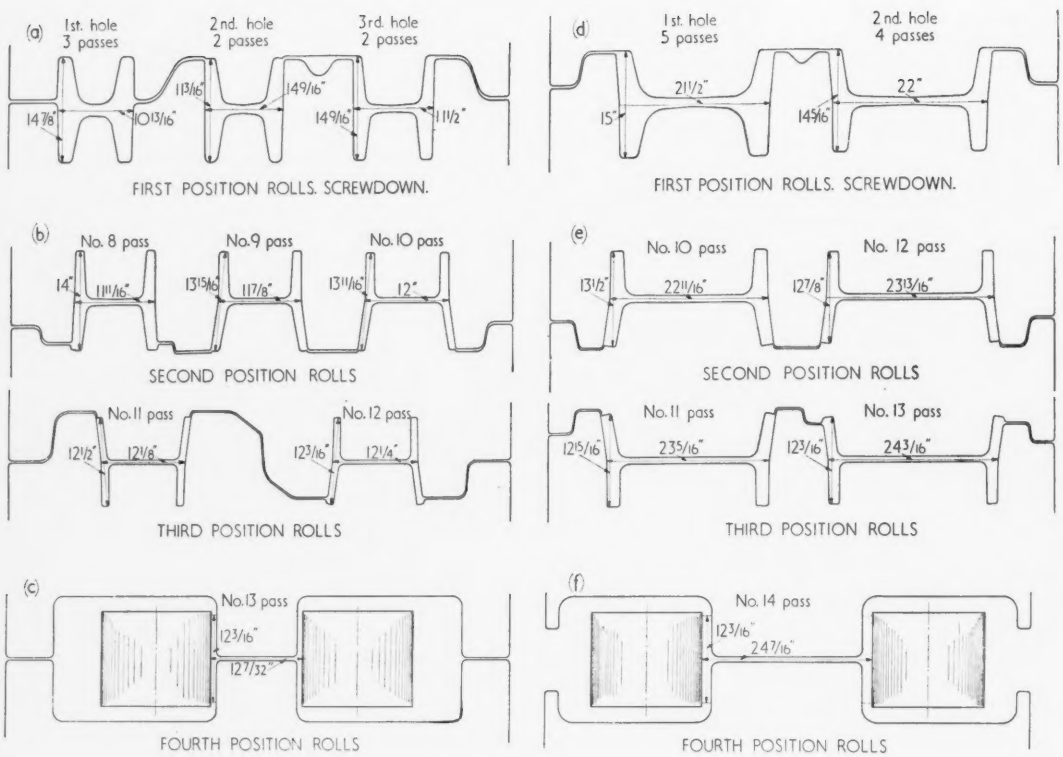


Fig. 3—Typical roll designs for broad flange beams of (*a*–*c*) 12 in. × 12 in. section and (*d*–*f*) 24 in. × 12 in. section

(a) (b) (c) (d)

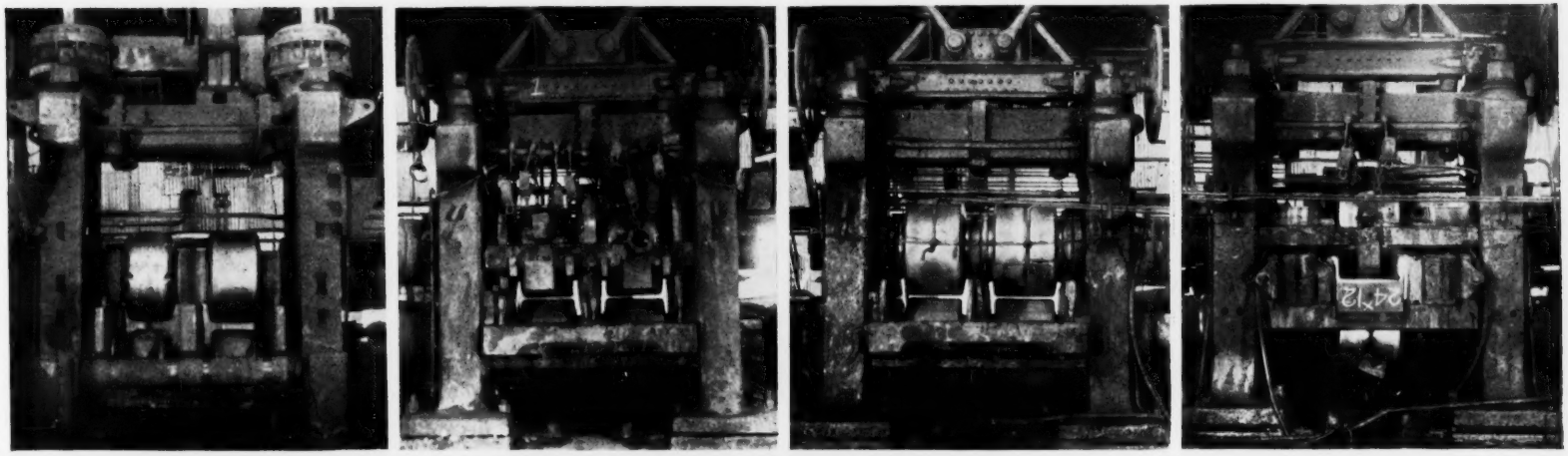


Fig. 4—Four stands shown in Fig. 3 : (*a*) First position ; (*b*) second position ; (*c*) third position ; (*d*) finishing position

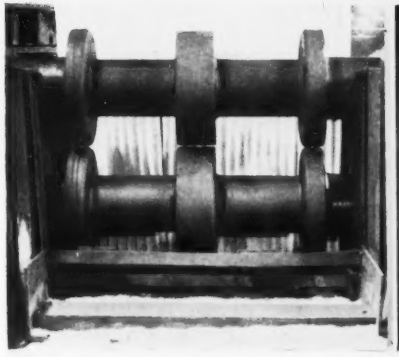


Fig. 5—Finishing rolls for 12 in. × 12 in. sections

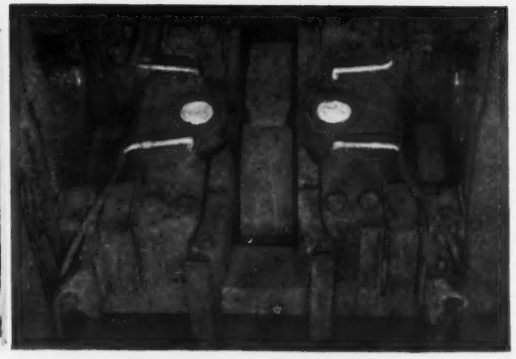


Fig. 6—Vertical rolls set for 12 in. × 12 in. sections

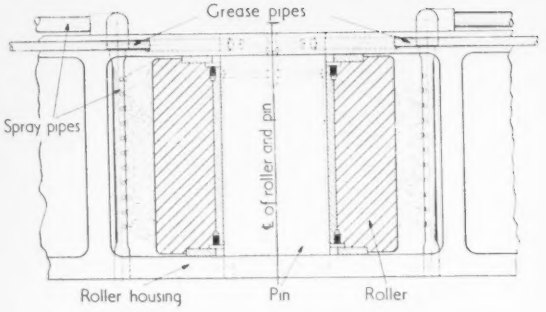
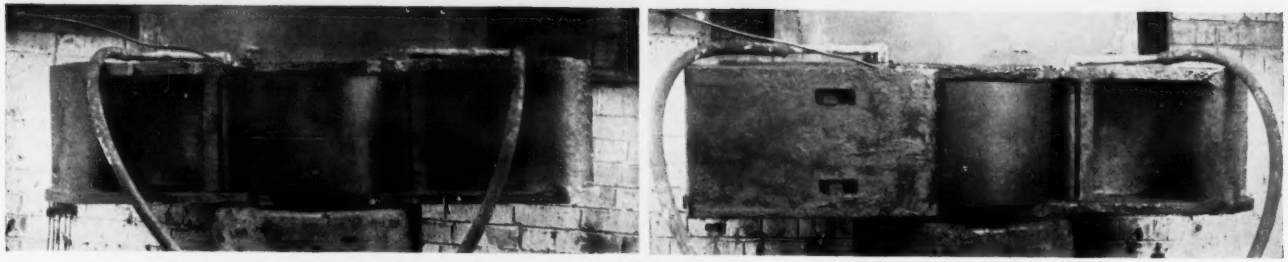


Fig. 7—Cross-section through vertical roller, showing lubrication and water spraying

(a)



(b)

Fig. 8—Vertical roll and housing with delivery horn (*a*) removed, and (*b*) in position

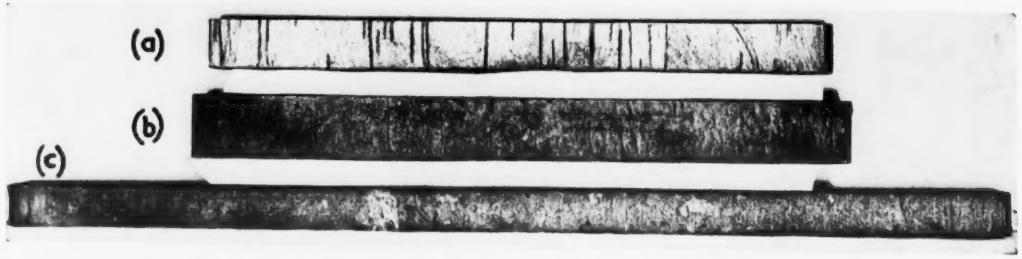


Fig. 9—Flanges from (*a*) a 24 in. × 7½ in. joist flange, (*b*) an 8 in. × 8 in. beam flange, and (*c*) a 24 in. × 12 in. beam flange

motor with a maximum operating horse-power of 12,100 and a cut-out of 14,500 h.p.

Three ingot sizes are used: 25 in. sq., weighing 4½ tons; 27 in. sq., weighing 5 tons 6 cwt.; and 30 in. sq., weighing 6½ tons. These cover the beam ranges very successfully and without waste.

Steel quality, unless otherwise specified, is to Lloyds-quality 28–33 tons tensile. Normally, it should contain 0·17–0·21% of carbon and 0·60–0·70% of manganese. On the larger sizes, the manganese content should be increased to 0·70–0·80%. This steel quality works well in the mill, and has reduced split flanges to a negligible quantity.

CONSTRUCTION AND OPERATION OF THE 32-IN. MILL

The 32-in. mill is fed from a wash-heating furnace that has a capacity of up to 100 tons/hr. There are two chargers, one for feeding the furnace with blooms from the cogging mill, and the other for withdrawing the reheated blooms and feeding the finishing mill. Either charger can do both jobs, so that the mill can be kept in operation if one or the other breaks down, although, on the faster orders, there is a slight reduction in output when this occurs. The mill itself is driven by two 4850-h.p., 54–140 r.p.m. electric motors, one at each end of the train. These motors are exactly similar to the one in the cogging mill, and each is capable of driving the four stands; in practice, however, two stands are generally driven with each.

There are four stands in the mill: the first, which has a screwdown, is fixed, and the other three are movable. The screwdown stand has an open top, and the roll change takes 1–1¼ hr. In front of this stand is a fixed table fitted with ruler-type manipulators, hydraulically driven and with electrically driven tipplers. These are a replica of the conventional modern-type cogging manipulators, but on a smaller scale; they can hold and control the entry into the grooves of the high-formed blooms that are necessary for producing the 12-in. flanges, thus preventing serious shearing of the bloom on the roll collars; and the record shift output of 701 tons on an 8-hr. shift proves that they are considerably quicker in manipulation than the normal type of finishing mill manipulator. This is the only fixed roller table in the mill; all the others are of the American movable type. There are two of these movable tables on each side of the mill. They are speedy in action and very easy and economical to maintain. Their main asset is the ease with which the bar can be passed forwards or backwards across the train, or passed between the driving spindles for a slack pass. This is very necessary when rolling the larger sizes of beams.

The three movable stands are lifted out of the mill, and housings, in which the rolls for the next section have already been mounted, are replaced. By two cranes on the mill gantry, each with a 60-ton heavy hoist and a 10-ton light hoist, it takes only 10–15 min. to change each respective stand, including uncoupling and recoupling of the spindle wobbler boxes. One crane uncouples and takes out, the other follows up with the replace and couples up. Each housing brought into the mill has the rolls completely fettled with horns, guides, etc., so that no time is lost with fettling in the mill.

Table I

NUMBER OF PASSES IN EACH POSITION IN THE FINISHING MILL

Size of Beam	Position				Total
	First	Second	Third	Fourth	
6 × 6	1	5	4	1	11
7 × 7	1	4	4	1	10*
8 × 8	1	4	4	1	10*
10 × 10	7	3	3	1	14*
12 × 12	7	3	2	1	13
14 × 12	7	3	2	1	13
16 × 12	11	2	2	1	16†
18 × 12	9	2	2	1	14†
20 × 12	9	2	2	1	14†
22 × 12	9	2	2	1	14†
24 × 12	9	2	2	1	14†

* On these sizes a repeat pass is made, usually through the last hole in the second position

† On these sizes a slack pass is made between the second and third position housings

DEVELOPMENT OF THE RANGE OF SECTIONS FROM 6 IN. TO 24 IN.

The first consideration was to design the roll passes to reduce to a minimum the total number of rolls that would be necessary for very quick roll changing.

The 7 in. × 7 in. and the 8 in. × 8 in. sections were incorporated in the roll design of the 6 in. × 6 in. section. The first-position rolls have two forming holes, one for 6 in. × 6 in. and the other for 7 in. × 7 in. and 8 in. × 8 in. A forming hole for 12-in. joists was also included. Figures 2*a* and *b* show the front and back views of these rolls. In Fig. 2*b* the forming hole on the left is for 12-in. joists, the middle one for 6-in. beams, and the one on the right for 7 in. × 7 in. and 8 in. × 8 in. beams. The bloom size entering the 6 in. × 6 in. former is 11 in. × 5 in., and that entering the 7 in. × 7 in. and 8 in. × 8 in. former is 12 in. × 6 in. The blooms from the cogging mill are considerably larger, generally 10 in. × 8 in. and 12 in. × 8 in. respectively, but can be varied according to ingot size and length of finished bar required. They are reduced to the required size in the slab or box holes. Three pairs of rolls are required for each size; *i.e.*, a 2nd, 3rd, and finishing pair. When these sections are due for rolling, the first position rolls are mounted at the weekend; and the roll change for beams can be done at any time during the current week. The time taken for this is 35 min. for a three-pair change, and is similar to the time taken to change for joists, sections, or rails.

The number of passes in the finishing mill for each size rolled is shown in Table I. The passes required to reduce the bloom size from the cogging to that required for entry into the first hole of the 6-in., 7-in., and 8-in. beams have been ignored. This bloom size could, if necessary, be supplied from the cogging, a larger size being made only to attain maximum output in that mill.

The 32-in. mill is invariably faster, even although it is used as a semi-cogging mill at such times. After this range—*i.e.*, from 10 in. × 10 in. upwards—the whole barrel length of all four stands is required for

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forming passes, so that no slabbing can be done and it is necessary to use a formed bloom from the cogging mill.

Figures 3*a–f* show typical roll designs for the 12 in. × 12 in. and the 24 in. × 12 in. sections, and Figs. 4*a–d* are photographs of these four stands in position in the mill.

On the 24-in. beam, the first-position rolls consist of two open flanges on the top side. Five passes are worked in the first groove, and this allows for maximum draft on the side of the flanges, without overloading. With the fairly generous taper, this helps to maintain their length. After these five passes, the bar is turned over before entering the second pass, to enable the thick close flanges that were on the bottom to be rolled to their correct thickness before the bar is transferred to the second-position pair of rolls.

On the 24 in. × 12 in. section, after the first pass in the 2nd position, the bar is transferred by the moving table to the first pass in the 3rd position. It is then passed back to the front side of the mill, between the 2nd and 3rd position housings, and entered into the second hole of the 2nd position. From there it is transferred to the second hole of the 3rd position and afterwards to the finishing pass. This method of working is adopted to avoid double or swing collars, for which there is not sufficient barrel length. The slack pass is used to bring the bar to the correct side of the mill in conjunction with the final pass. This could be done by repeating the entry into one of the holes in the 2nd or 3rd positions, as in the smaller sizes (*see* Table I), but there is some danger to the rolls and gear by repeating with such a heavy bar.

The minimum of taper is used in the flange grooves through the train, until, at the penultimate pass, this is only 8° in the top or open flange and 1° in the bottom. Generally, these tapers vary from between 8° to 10° in the open flanges and 1° in the closed flanges. In the first-position rolls, both open and closed flanges have a taper of 5°. In the penultimate pass, a joint hole also is used; it is near the top of the open flange and on the top side, except in the 12 in. × 12 in. section, when it is on the bottom side. Its main purpose is to control the length of the flange; *i.e.*, its action is similar to that of a close hole for controlling flange length, but it is also capable of taking a fair amount of side draft.

The second, third, and finishing positions are entirely separate for each size. The finishing rolls for the 12 in. × 12 in. section shown in Fig. 5 are typical of all sizes.

The small diameter of the roll, which is only 18 in. when the rolls are new, is necessary to allow the vertical roll housings to be entered. This has proved to be quite satisfactory, even though the 3rd position is driven through the finishing position, and no failure of rolls has occurred. On the smaller sizes of beams, iron rolls are used quite successfully.

When the beams were first rolled, the fillets were cut to the exact flange length, but fins formed on the flange tips, especially at the front and back ends of the bars, owing to the passage of steel between this fillet and the vertical rolls. As the flange length and tips were virtually finished when rolled in the last hole of the 3rd position, these fillets were cut away; this stopped the finning and still retained a perfect flange. As the width of the window on the 24-in. finishing (*see* Fig. 3*f*) was narrower than the housing, the end collars had to be cut away almost entirely to allow the vertical housings to be inserted. It was just possible to leave enough material to act as thrust collars. When these rolls are built up, a test piece the thickness of the web is placed between the webs of the top and bottom rolls. This is taken out when the housing is set in the mill and the pressure on the top roll carrier chocks is put on.

VERTICAL ROLL HOUSINGS

The photograph in Fig. 6 is taken looking down on the vertical roll housings, after they had been set and before the top roll had been placed in position. The vertical rolls are adjusted to their correct position by the four wedges, liners being used at the front of these for rough adjustment. The cramp bars are machined from mild-steel blooms, and these are standard for all sizes of beams. On the smallest beam (*i.e.*, 6 in. × 6 in.) 9-in.-thick blocks are inserted between the wedges and the vertical roll housings; decreasing block thicknesses are used for increasing beam widths up to 24 in. when only shims are required.

The housings themselves were fabricated from mild-steel plates about 1½ in. thick. These were quite satisfactory at the start, but they became distorted after a few months' use. They were then cast in steel, and such housings are now standard. The eight 2-in. holding-down bolts are tightened up when the vertical wheels have been adjusted to give the correct flange thickness. After this, very little adjustment of the housings is necessary during the actual rolling and, in fact, they are seldom moved.

VERTICAL ROLLS

The vertical rolls are now made in best quality, untreated, high-tensile cast iron, and they wear excellently. They do not need changing, even in a rolling of 1000 or 1500 tons. When new, their diameter is 16 in., and they are discarded when it reaches 14 in. Only very slight dressing is carried out, when necessary, and $\frac{1}{16}$ in. off the diameter is all that is required. A roll should have a life of 60,000–70,000 tons.

Initially these rolls were made in cast steel and heat-treated; their analysis was:

	%
C	0·60
Mn	0·65
Ni	1·40
Cr	0·70

Although their wearing qualities were good, the rolls proved to be too brittle; small pieces dropped out, welding was necessary, and three of them broke in half. The cause, to some extent, may have been faulty lubrication and inadequate cooling. These latter problems were overcome by fitting forced grease lubrication to the bearing, and by introducing water sprays inside the housings, with direct water impingement on to the rolls. Figure 7 is a cross-section of the vertical rolls, showing the present lubrication and water-cooling arrangements.

Figures 8*a* and *b* show the roll and housing, with and without the delivery horn. At first this horn was not fitted, one being fastened to the cramp bar. This proved satisfactory for delivery of the bar, but was not proof against a flange tearing from the web and going round the vertical roll. After this had occurred on three or four occasions, the horn was fitted to the roll housing, as shown in Fig. 8*b*. It is held in position by two bolts in slotted holes, so that it can be adjusted to bear on the roll.

The roll spindles are 7 in. dia., and 16½ in. long; a phosphor-bronze bush is used, which is 12 in. long, $\frac{17}{32}$ in. thick, and bored to suit the spindle and to be a press fit into the roll. There are also phosphor-bronze thrust plates at each end. Spiral grease grooves $\frac{3}{8}$ in. wide and $\frac{1}{16}$ in. deep are cut in both the bush and the thrust plates. The grease used is suitable for a temperature up to 250° F.

The amount of work on each wheel, apart from the straightening up of the flanges, is $\frac{1}{16}$ in., but this can be increased without any undue strain on either the wheel or the housing. For experimental purposes, the flange thickness has been reduced by $\frac{1}{8}$ in., without damage to the gear. One point that should be noted is the considerable elongation of the flanges, with only a slight decrease in their thickness: they increase by $\frac{1}{16}$ in. when the thickness is reduced by 0·02 in. There is no doubt that the excellent flow of steel up the flanges similar to those shown in Fig. 9, compared with that of an ordinary joist flange, is due to the method of rolling the flanges and the positive pressure of the wheel on the stock, which tends to flow the steel up and down towards the open fillets. The flow lines in the beams do not run out to the edge of the flange, as they do on the joist, which—for the strength in the bar—is a great asset.

STRAIGHTENING OF BEAMS

The cooling and straightening of the beams have not presented any problems. On the larger sizes, a gap of about 12 in. is left between each bar on the cooling banks, so that any distortion that takes place when the bars are boxed closely together is nullified. The cold straightening is done on heavy side-press machines, and weight for weight throughputs are better on beams than on joists. Apart from the actual straightness of the bars, there is very little distortion in the flanges; they are invariably square to the web, because the vertical wheels act as perfect delivery guides.

WEIGHTS AND PROPERTIES OF BEAMS

The weights and properties of the beams were decided after studying American and German standards. They follow closely the German range, and on a number of sizes they are midway in the range of the American weights. Since the range of 6–24 in. was completed, rolls to produce a 75-lb. 12 in. × 12 in. beam, and a 90-lb. 14 in. × 12 in. beam have been turned. Weights per foot can be increased slightly by thickening up the webs; this elongates the flanges in direct proportion, but very little variation in the flange thicknesses can be made without cutting the rolls to the thickness required.

Table II

RANGE OF BEAMS NOW PRODUCED

Size, in.	Weight, lb./ft.	Area, sq. in.	Thickness	
			Web	Flange
6 × 6	25	7·35	0·31	0·46
7 × 7	34	10·00	0·35	0·55
8 × 8	45	13·23	0·39	0·64
10 × 10	63	18·42	0·43	0·72
12 × 12	75	22·06	0·43	0·71
12 × 12	83	24·28	0·47	0·79
14 × 12	90	26·47	0·50	0·826
14 × 12	100	29·41	0·55	0·92
16 × 12	110	32·35	0·55	1·00
18 × 12	122	35·88	0·59	1·08
20 × 12	135	39·71	0·63	1·16
22 × 12	150	44·12	0·65	1·28
24 × 12	165	48·53	0·70	1·36

Table II gives the full range of beams that can now be produced. In a few months' time, when a fifth stand has been installed, it will be possible to increase the range up to 30-in.-wide beams, giving beam sizes of either 30 in. × 10½ in., which is the American standard, or 30 in. × 12 in., which is the German standard. In addition to reducing roll changes, it will also enable any British Standard joist from 6 in. to 24 in. × 7½ in. to be rolled as a beam with parallel flanges and, in most cases, with a reduction in wt./ft.

OUTPUTS AND ROLL LIFE

The present outputs in an 8-hr. shift vary from 300 tons in the lightest sizes to 420 tons in the heavier ones. These outputs are slowly increasing as the mill crews become more conversant with the method of rolling, and the delivery guides are made more efficient. Delivery guides were a problem at first, because the flange guides have to do a considerable amount of work in stripping the stock from the roll, as compared with an ordinary joist, the flange taper being much reduced in the beam. Roll life is equal to that of joists, or greater in the finishing pair. On beams, these rolls are turned when new to the maximum depth, which is + $\frac{1}{8}$ in. Owing to the vertical flanges, the depth of beam, unlike that of a joist, is decreased on every dressing until it reaches its minimum of − $\frac{1}{8}$ in. As the amount of work on the web of the finishing pass is very small, only very slight dressing is necessary; thus, when the depth has reached the minimum, the actual roll diameter is still well within the minimum roll centres. By turning the roll to the next size down—a 24 in. to a 22 in., a 12 in. to a 10 in., and so on—its life may be greatly extended.

SUMMARY AND CONCLUSIONS

It has been proved that parallel flange beams can be successfully produced without abnormal roll wear or roll failure, in a mill originally designed for the production of sections and rails. This would not have been possible without four stands, and it would have been difficult to produce the heavier sizes if the mill had had a floor with skid gear instead of with moving tables.

XUM

The rolling of beams has in no way affected the normal production of rails, sections, piling, etc., as no alterations that would adversely affect normal level of production have needed to be made. In fact, such alterations as have been made have increased the efficiency of the mill.

The sizes and weights per foot of the range of beams produced covers most normal requirements of the structural engineer. When the fifth stand is installed, lighter weights in the respective sizes can be rolled, if the demand for these justifies the cutting of rolls. The market, especially in this country, for sizes over 24 in. wide, with perhaps the exception of a 30 in. × 10½ in. beam, would seem to be very small, and the demand should be met by welded fabrication.

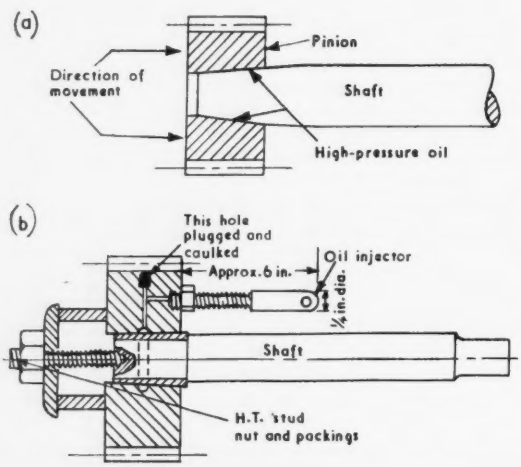
The electric drives are ideal for this method of rolling. Steam engines would probably be unsuccessful, as the steam drive is very rough by comparison and snatches at the bar when it enters into the pass. On the deep small taper flanges, this would be fatal with the fettling gear and injurious to collars and rolls.

It is appreciated that varying weights in each size can be rolled in the Grey-type mill, but it is debatable whether this is really necessary when it is considered that the high capital cost of such plant has to be recovered, and that joists rolled in one size and one weight have successfully covered the requirements of the structural engineer for a considerable number of years.

Oil Injection Shrink Fitting

By J. A. Abrahams, B.Eng., G.I.Mech.E.

EVERY steelworks maintenance engineer knows of the trouble that is experienced with badly fitted keys, particularly where the part keyed to a shaft is subject to reversal of motion. To minimize these difficulties, the method of oil injection developed by SKF Gothenburg has been widely adopted by the English Steel Corporation, Ltd. The simplest form of this method consists in tapering the mating surfaces (*see* diagram (*a*)), expanding the part to be fitted by forcing high-pressure oil between the surfaces, pushing it up the tapered portion of the shaft to the correct position, and then releasing the pressure. In practice it is usually inconvenient to use a tapered shaft, and therefore a sleeve is introduced between a parallel shaft and the part to be fitted (*see* diagram (*b*)). The stud shown on the end of the shaft, with a packing between it and the pinion that is to be fitted, is used in mounting the part accurately; also, it is essential for removal to restrain the pinion, which is liable to fly off violently when the oil pressure is applied.



The advantages of the sleeve arrangement are that the part may be positioned precisely on the shaft without prejudice to the degree of interference, and that the sleeve may be used as a gauge when boring the part to be fitted.

The key to success is the accurate machining of all parts to the tolerances laid down, and any shortcomings in this respect may lead to difficulties.

Advantages of the oil-injection method of fitting may be summarized as follows:

(i) The speed with which plant parts can be changed on renewal due to wear, etc. With overhead travelling cranes, for example, this method eliminates, in most cases, the necessity for bringing electric motors and shafting to the floor when changing the part

(ii) Elimination of the constant attention necessary to many fitted keys

(iii) Elimination of the ill effects of badly fitting keys; *e.g.*, replacement of gears, shafts, couplings, etc., occasioned solely by damaged keyways, and particularly the expensive replacement of electric motor armature shafts, often calling for the rewinding of the armature

(iv) Unlike the keys, the same sleeve can be re-used almost indefinitely.

The following example illustrates the advantages of the method. The electric motor for an ingot planing machine had a half coupling keyed to the 3¼-in. dia. armature shaft by means of three keys spaced at 120°. From 1938 to 1950 the armature shaft had to be replaced every two years, owing to keyway trouble. In addition, there were numerous stoppages for the refitting of keys. A new half coupling using oil shrink fitting was installed two years ago, and no further trouble has been experienced.

The process is covered by patents held by the SKF Company in Sweden, but permission to make use of the method in this country should be negotiated with the Skefko Ball Bearing Co., Ltd., Luton, who act as agents for SKF Gothenburg in this matter.

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Mr. Abrahams is with the English Steel Corporation Ltd., Sheffield.
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Ingot Heat Conservation

By

L. H. W. Savage, M.Sc., F.R.I.C.,

and R. T. Fowler, Ph.D.

COOLING OF 8-TON INGOTS BETWEEN TEEMING AND STRIPPING

SYNOPSIS

A detailed description is given of the method by which heat transfer from a steel ingot can be determined by using the mould as a calorimeter.

Although the heat loss from the steel is not a simple function of time, it can be closely represented for 8-ton slabbing ingots in a casting pit by the equation

$$\text{Heat loss from steel} = at^n$$

when t is the time from start of teem, and a and n are functions of the initial teeming conditions. Over the range studied, the value of the exponent n does not vary widely from 0·5, and the simpler form

$$\text{Heat loss from steel} = b\sqrt{t}$$

gives only slightly greater error and is easier to apply. The coefficients a, b, and n can be adequately represented as linear functions of the initial mould temperature, the other initial variables being less significant.

The heat lost by the steel can also be closely related to the mould surface temperature at a single reference point, and this relation has been used to show that there is little difference in heat loss between ingots in different parts of the pits.

The method of estimating the temperature distribution in the steel and the amount solidified at various times is also detailed.

Graphs are presented to show how the results can be applied by operating personnel to reduce track times and heating times of ingots.

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Introduction

The cooling of 8-ton rimming-steel slabbing ingots in a casting pit between teeming and stripping has been the subject of a series of investigations for the Fuel Committee of the British Iron and Steel Research Association, so as to learn more about the heat content and temperature distribution of the ingots, with the object of improving casting-bay and soaking-pit practice.

In a previous paper,[1] the technique used to estimate the heat loss from a horizontal mid-height section of a steel ingot was described, and the results were given for nine casts of rimming steel. The results obtained showed an appreciable variation which, it was considered, could be due to variation in initial steel temperature, initial mould temperature, time from tap to teem, and pit position and surrounding hot moulds, but the data were insufficient to separate or assess these factors.

A second series of nine casts has now been studied, using a similar technique, with 40 thermocouples inserted through the walls of a test mould to obtain further data. It had also been found[1] that the heat gained by the mould, and consequently the heat loss from the steel, could be estimated approximately from the temperature rise of a single thermocouple on the outer surface of the mould, and so a single thermocouple was fixed to the centre of the long face of six of the other moulds in each cast. This enabled any differences in mould position for the same initial conditions to be ascertained.

The first purpose of the present paper is to detail fully, for the benefit of future investigators, an experimental technique that has proved satisfactory and supersedes those described earlier, together with the methods by which the results have been calculated from the experimental data.

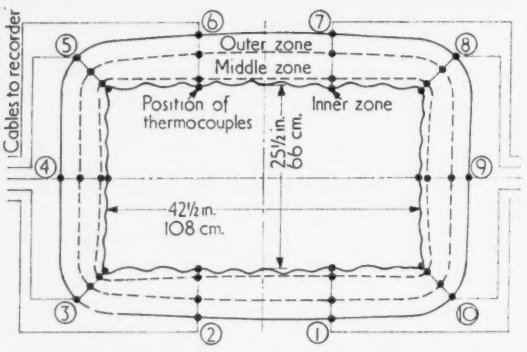
The second purpose is to ascertain whether heat loss from an ingot to its mould and surroundings can be expressed, with sufficient accuracy for industrial application, as a simple function of time and the more or less uncontrolled variables, such as initial steel temperature, initial mould temperature, and proximity of other moulds in the same cast. It is not to be expected that any simple function will be more than a crude approximation to a complex problem in unsteady heat flow, which is not even amenable to mathematical analysis.

The third purpose is to ascertain whether the degree of solidification of the cooling ingot, which can be approximately estimated from measurements of heat transfer and mould temperature, can also be expressed as a simple function of the variables.

The final purpose is to discuss the application of the results to works practice by modifying empirical rules for stripping and soaking times.

Paper PE/A/11–12/52 of the Plant Engineering Division of the British Iron and Steel Research Association, first received 8th July, 1952, and in its final form on 4th November, 1952. The views expressed are the authors', and are not necessarily endorsed by the Committee as a body.

Mr. Savage is Head of the Fuel Technology Department of the Plant Engineering Division of the British Iron and Steel Research Association, and Dr. Fowler, formerly with the Association, is now Lecturer in Chemical Engineering at the University of Sydney.



Weight of 1-cm. thick section of mould, kg.		*Weight of 1-cm. thick section of steel, kg.*	
Inner zone	5·975	Rimming steel	48·32
Middle zone	22·257	Killed steel	52·20
Outer zone	18·517		
		Length of perimeter, cm.	
Total	46·749	Mould	423
		Ingot	350

Mould height	74 in. (188 cm.)
Mould total weight	8·8 tons (8·94 tonnes)
Ingot total weight (nominal)	8·0 tons (8·13 tonnes)

Fig. 1—Horizontal mid-height section of test mould

List of Symbols and Units Used

- a Proportionality constant; semi-major axis of ingot = 54 cm. (21·3 in.)
- b Semi-minor axis of ingot = 33 cm. (13·0 in.)
- c Specific heat of steel (assumed to be constant at 0·16 cal./g. over range 1000–1530° C.)
- Fx Instantaneous net heat flux, cal./sq. cm. sec.
- H_m Heat gain by mould, cal./g. of steel
- H_{re} Surface heat loss, cal./g. of steel
- H_s Heat loss from steel, cal./g.
- H'_s Superheat in steel above liquidus temperature, cal./g.
- L Latent heat of solidification (assumed to be 65 cal./g.)
- M Mass of steel in mid-height section, g.
- n Exponent
- P Surface area of ingot section, sq. cm.
- Q Total heat loss, excluding superheat by ingot, cal.
- s Distance solidified normal to surface, cm.
- t Time from metal reaching mid-height section, min.
- t' Time interval between strip and start of subsequent teem, hr.
- θ_m Initial temperature of mould, ° C.
- θ_s Temperature at surface reference point, ° C.
- θ'_s Average temperature of inner surface of mould, ° C.
- θ_{st} Initial temperature of steel, ° C.
- θ_0 Average surface temperature of ingot, ° C.
- θ_1 Liquidus temperature of steel (assumed constant at 1530° C.)
- ϵ Effective emissivity, assumed to be 0·5 where ϵ (steel) = 0·53 and ϵ (mould) = 0·90
- ρ Density of steel: taken as 6·67 g./c.c. (0·238 lb./cu. in.) for rimming steel and 7·3 g./c.c. (0·260 lb./cu. in.) for killed steel
- σ Stefan's constant: $1·36 \times 10^{-12}$ cal./sq. cm. sec. ° K⁴.

EXPERIMENTAL TECHNIQUE

The basis of the experimental technique is to measure the temperatures continuously at a large number of points throughout the walls of an ingot mould, and to use these temperatures to calculate the change in heat content of the mould and the heat loss by radiation and convection from its outer surface, which can then be used to calculate the heat loss from the steel.

Up to the present, such measurements have only been made on a mid-height section of an 8-ton slabbing-ingot mould in a casting pit. This zone of the mould, and thus the corresponding zone of the ingot, are least affected by longitudinal heat flow, and are the slowest to respond to external temperature changes.

To use an ingot mould as a calorimeter, ten ½-in. dia. holes were drilled through the mould wall on the mid-height plane in the positions shown in Fig. 1, so that they were approximately equi-spaced and, with the exception of the corners, corresponded with the top of a corrugation of the inside face. The first inch of each hole was tapped ⅝ in. to allow the thermocouple plugs to be screwed into position.

The thermocouple plugs, which were the same as those used in the earlier experiments,[1] were constructed from cast iron of the same composition as the mould, the lengths corresponding to the thickness of the mould wall at the various positions, so that the ends were flush with the inner and outer faces. Four holes were drilled through each plug, into which were inserted chromel and alumel wires, the hot junctions of the thermocouples being formed on the centre-line of each plug by clamping each pair of wires tightly with a set screw. The leads, insulated with silicone-impregnated glass-fibre sleeving, were secured in longitudinal slots at the sides of the plug.

The thermocouple wires from each half of the mould were insulated with refractory beads for 2 in. and then with glass-fibre sleeving, and were bound with asbestos tape into two cables, each leading to two 24-pin sockets about 15 ft. away from the mould. This arrangement allowed the sockets to be placed on the side of the pit remote from the furnace, where they were cooler and not subject to damage by slag from the launder, even if the mould was placed on the furnace side of the pit. The bound cables were firmly secured by wire to ½-in. bolts screwed into the mould, so that there was little strain on the wires leaving the thermocouple plugs.

Each pair of 24-pin sockets was connected by plugs to an 80-ft. cable containing 22 copper and 22 constantan wires, insulated by glass-fibre sleeving and bound with asbestos tape. The other ends of these two cables were connected by 12-pin plugs and sockets to a multi-point switch box,[2] and thence to a 12-point high-speed recording potentiometer. The two spare copper and constantan wires in each cable were used to form a thermocouple in each of the multi-pin plugs, so that the temperature could be continuously measured at the junction of the chromel and copper, and of the alumel and constantan. The remaining four thermocouple positions on the switch box were used as ' markers '[2] for identifying the four cycles of the recorder, which were completed in less than 1 min.

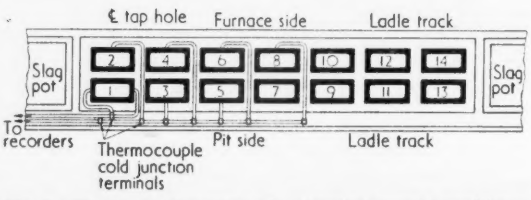


Fig. 2—Diagram of casting pit, showing mould positions

In the works at which the experiments were conducted, steel is top-teemed into moulds set in pairs in a casting pit, shown diagrammatically in Fig. 2, from a ladle held in a ladle carriage. After the test mould had been set in position, the 80-ft. connecting cables were laid between the ladle track and the casting pit, the 24-pin plug and socket junction boxes being placed at the top of the wall and further protected by covering with asbestos cloth. Thin steel sheets were placed to bridge the top of the test mould and the adjacent moulds, so as to reduce risk of damage to the thermocouples through liquid-steel splashes or a running nozzle, but were removed as soon as possible after the completion of teeming. The junctions were disconnected immediately before stripping, but were remade as soon as the mould had been set on the bank in order to take observations on the rate of cooling of the mould and to check the thermocouple circuits.

The temperature of the liquid steel was determined by means of a dip thermocouple in the bath of the furnace immediately before tapping, and again at the top of the teemed test mould as soon as the ladle carriage had been moved away.

During the second series of casts, chromel–alumel thermocouples were also attached to six of the other moulds, using ½-in. dia. cast-iron plugs, similar in construction to those used by Brancker,[3] which were screwed into the centre of the long face adjacent to the pit wall. The leads were sheathed in glass-fibre sleeving and connected to a main cable on the wall of the casting pit by 2-pin plugs and sockets. The main cable was connected to a 6-point slow-speed recording potentiometer placed in a cool position in the casting bay.

METHOD OF CALCULATING HEAT LOSS FROM STEEL

Heat loss has been calculated from a 1-cm. thick section at mid-height of the ingot, and it has been assumed that heat transfer perpendicular to this section is negligible. Although this is not strictly true, the differences between different ingots due to this should certainly be of a second order.

Heat Gain by Mould

On the completion of each trial, the temperatures of the 40 thermocouples were tabulated at intervals of 10 min. from the start of teem, and the corresponding heat contents were ascertained, using the data given by Hatfield,[4] which were considered appropriate for the cast iron in the mould used.

The mid-height section of the mould was considered to be divided into three zones (*see* Fig. 1), the points of temperature measurement lying on the zone boundaries. The areas of these zones were determined, and the weights of a 1-cm. slice calculated, a density of 7·037 g./c.c. being assumed.[4] Since the thermocouples were approximately equi-spaced around the zones, the average heat content of each zone was

Table I

METHOD OF CALCULATING HEAT LOSS FROM MID-HEIGHT SECTION OF STEEL (TRIAL NO. 7)

Time from Start of Teem, min.	2	3	4	5	10	20	30	40	50	60	80	100	140	180	200
Heat Gain by Mould															
Heat content of mould iron at points of temperature measurement, cal./g. of iron															
Inner thermocouples (average)	24·0	36·9	42·6	44·6	48·2	57·8	65·8	73·7	79·7	84·3	91·0	94·8	98·2	97·6	95·0
Second "	12·1	22·1	28·8	32·9	43·3	53·9	63·9	71·3	77·3	82·3	89·7	93·8	96·4	96·1	94·8
Third "	5·7	9·2	12·0	15·2	26·8	42·4	52·9	61·6	68·8	74·6	82·5	87·2	90·8	91·1	89·7
Outer "	4·4	7·5	9·4	12·0	22·1	38·4	48·8	56·6	64·0	69·4	77·3	81·5	85·9	85·5	84·2
Heat content of zones in mid-height section, kg.cal.															
Inner zone (weight 5·975 kg.)	108·1	176·3	212·7	231·2	311·7	332·2	388·4	432·6	469·0	498·9	540·1	565·2	581·3	578·7	567·0
Middle zone (" 22·257 kg.)	200·3	347·2	449·6	534·2	776·8	1068·3	1302·0	1477·8	1624·8	1747·2	1916·3	2016·5	2083·3	2083·3	2053·2
Outer zone (" 18·517 kg.)	92·6	153·7	198·1	250·0	451·8	749·9	944·4	1096·2	1231·4	1333·2	1479·5	1561·0	1636·0	1635·1	1610·1
Total heat content in mid-height section	401·0	677·2	860·4	1015·4	1540·3	2150·4	2634·8	3006·6	3325·2	3579·3	3935·9	4142·7	4300·6	4297·1	4230·3
Initial heat content at 20° C.	116·9	116·9	116·9	116·9	116·9	116·9	116·9	116·9	116·9	116·9	116·9	116·9	116·9	116·9	116·9
Heat gain by mid-height section	284·1	560·3	743·5	898·5	1423·4	2033·5	2517·9	2889·7	3208·3	3462·4	3819·0	4025·8	4183·7	4180·2	4113·4
Heat gain by mould, cal./g. of steel	5·89	11·61	15·41	18·62	29·46	42·09	52·12	59·82	66·41	71·67	79·05	83·33	86·60	86·53	85·15
Heat Loss from Mould Surface															
Average outer surface temperature, °C.	35	60	75	95	175	295	372	417	465	505	550	582	600	598	591
Instantaneous heat flux, cal./sec./g. of steel															
Convection	...	...	...	...	0·25	0·48	0·65	0·75	0·83	0·93	1·04	1·11	1·17	1·15	1·14
Radiation	...	...	...	...	0·39	1·15	1·88	2·48	3·04	3·81	4·92	5·64	6·07	5·99	5·81
Total	...	...	...	...	0·64	1·63	2·53	3·23	3·87	4·74	5·96	6·75	7·24	7·14	6·95
Incremental heat loss over interval, cal./g. of steel			Negligible		0·19	0·68	1·25	1·73	2·13	2·58	6·42	7·63	8·40	8·63	8·45
Cumulative heat loss, cal./g. of steel					0·19	0·87	2·12	3·85	5·98	8·56	14·98	22·61	31·01	39·64	48·09
Total Heat Loss from Steel, cal./g.	5·89	11·61	15·41	18·62	29·65	42·96	54·24	63·67	72·39	80·23	94·03	105·94	117·61	126·17	133·42

assumed to be the arithmetic mean of the heat contents corresponding to the temperatures of the 20 thermocouples enclosing each zone.

The average heat contents of each zone were multiplied by the appropriate weights of the zones and added together to give the total heat content of the mid-height slice. This procedure gave a more accurate estimate than the simpler method of ascertaining the heat content corresponding to the averaged temperatures, particularly when temperatures were at or above the recalescence zone of the cast iron. The heat gain by the mould was obtained from the difference of the heat content at the various times and the initial heat content of the mould.

Heat Loss from Mould Outer Surface

The convection loss from the mid-height section of the mould was calculated assuming natural convection to air at 20° C. from a vertical surface at the average temperature of the mould surface.

The radiation from the outer surface was also calculated, assuming an emissivity of 0·9 and reducing the surface area by an amount depending on the proximity of other hot moulds. The instantaneous heat flux due to convection and radiation was calculated at 10-min. intervals, and the cumulative heat loss was estimated by assuming that the flux changed linearly over each time interval.

The surface heat flux was also calculated from the temperature gradients at the surface and the rate of change of heat content of the outer zone of the mould section.[5] The temperatures, however, could only be assumed to be accurate to $\pm 2\frac{1}{2}$° C., and so the percentage error on a temperature gradient could be very much higher than that of the surface temperature alone; thus, the first method of calculation, which gave rather lower values of heat loss, has been used.

Heat Loss from Steel

The total heat loss from the steel, neglecting longitudinal heat transfer, was obtained by adding the convection and radiation loss to the heat gain by the mould at the various time intervals, and was most conveniently expressed in heat units per unit mass of steel, *i.e.*, cal./g. or therms/ton. The density of the ingots was obtained from a number of test weights and found to give mean values of 6·67 g./c.c. (0·238 lb./cu. in.) for rimming steel and 7·30 g./c.c. (0·260 lb./cu. in.) for killed steel. The calculations for one of the trials are given in Table I, the results of all the trials in Table II, and the initial conditions in Table III.

INFLUENCE OF INDEPENDENT VARIABLES

Consideration of the results shows that there is a marked variation in the heat gain by the mould and also in the heat loss by the steel between the different trials at the same time interval. For any one trial, the heat loss can be represented as a smooth curve against time from the start of teem, which approximates to a power curve ($H_s = at^n$, where $n < 1$). It is not, however, to be expected that a simple power function should characterize the curve, because the complex mechanism of the heat transfer involves conduction, radiation and convection, latent heats of transformation, and variable thermal properties in both the steel and mould materials. A relatively simple power function would, however, probably be sufficiently accurate for most industrial applications concerning time for stripping.

Time is obviously the major variable in all cases. The differences between the results of the trials at any one time may be due primarily to differences in the initial mould temperatures, the initial temperature of the steel when teemed, and the proximity of other hot moulds, which may affect the rate of heat loss from the outer surfaces of the mould.

The results of the trials have been analysed in two different ways to assess the relative effects of these independent variables: firstly, on a time basis, which is only appropriate for moulds in comparable positions, and secondly, on a basis of the temperature at a particular point on the mould outer surface, which should be able to include moulds in any position in the casting pit. The latter may be of greater application in the future when contact surface pyrometers of a sufficient degree of accuracy have been developed. Conventional methods of analysis[6] have been used throughout, and the variables have been assumed to be of real significance if there is a chance of less than 1 in 100 that the effect was accidental.

Correlation with Time as the Main Variable

It has been assumed that for each trial the heat loss from the steel can be expressed by the formula

$$H_s = at^n,$$

where a and n are constants for each trial but will be affected by the initial temperatures of the steel and mould. The values of a and n that gave the best fit to the values of H_s in Table II were ascertained for each trial by conventional methods.

The assumption was then made that a and n were linear functions of the initial mould temperature θ_m and of the initial steel temperature θ_{st}, either as measured in the bath, or after arbitrary correction for cooling in the ladle, assuming a temperature fall of 20° C., plus 1° C./min. between tap and start of teem of test mould.[7] The values of a and n obtained for each trial were correlated with these temperatures, and it was found that the initial mould temperature had an appreciable effect with a high statistical significance, whereas the steel temperature had a much smaller effect and a low significance. In consequence, the parameters a and n could be expressed respectively as

$$\begin{aligned} a &= 13{\cdot}097 - 0{\cdot}029066\theta_m \text{ cal./g.} \\ \text{or} \quad &\quad 0{\cdot}528 - 0{\cdot}001170\theta_m \text{ therms/ton} \\ n &= 0{\cdot}421 + 0{\cdot}000770\theta_m \end{aligned}$$

Over the range of initial mould temperatures investigated, the value of the parameter n varied from 0·47 to 0·58. A value of 0·5 has been used by other workers,[8] and a further correlation was then carried out to find the best value of the parameter a in the equation

$$H_s = at^{0{\cdot}5}$$

resulting in

$$\begin{aligned} H_s &= (11{\cdot}09 - 0{\cdot}00830\theta_m)\sqrt{t} \text{ cal./g.} \\ \text{or} \quad &\quad (0{\cdot}443 - 0{\cdot}000330\theta_m)\sqrt{t} \text{ therms/ton.} \end{aligned}$$

This equation accounts for slightly less of the total variance than the former, using an exponent that

Table II

TEST RESULTS

Time from Start of Teem, min.	Trial No.	7	8	9	10	11	12	13	14	15	17	18	19	20	21	22	23	24	25
	Initial mould temperature, ° C.	20	80	155	107	150	191	164	220	179	100	130	111	101	96	120	120	89	116
	Temperature of steel before tap, ° C.	1592	1580	1580	1608	1600	1592	1584	1590	1587	1599	1590	1593	1573	1603	1580	1580	1598	1598
	Time from tap to teem, min.	17	20½	14	9	8	14¼	17	7½	10	12	9	12	13	8	8½	8	7	5
10	Heat gain by mould, cal./g. of steel	29·46	27·80	26·42	29·84	27·65	25·11	25·58	26·18	25·57	31·42	28·74	29·69	30·49	29·46	29·21	29·90	31·65	28·25
	Convection and radiation loss, ,, ,,	0·19	0·23	0·40	0·30	0·36	0·50	0·41	0·59	0·48	0·23	0·27	0·26	0·26	0·22	0·29	0·30	0·32	0·26
	Heat loss from steel, ,, ,,	29·65	28·03	26·82	30·14	28·01	25·61	25·99	26·77	26·05	31·65	29·01	29·95	30·75	29·68	29·50	30·20	31·97	28·51
	Reference-point temperature, ° C.	175	200	270	257	275	300	264	320	310	230	230	228	220	215	237	290	199	225
20	Heat gain by mould, cal./g. of steel	42·09	40·39	39·37	43·65	42·98	39·13	37·20	39·43	37·71	44·30	44·49	42·53	44·63	44·23	40·79	40·58	44·98	39·46
	Convection and radiation loss, ,, ,,	0·87	0·81	1·20	0·96	1·15	1·46	1·12	1·61	1·35	0·82	0·85	0·86	0·87	0·73	0·81	0·91	0·98	0·75
	Heat loss from steel, ,, ,,	42·96	41·20	40·57	44·61	44·13	40·59	38·32	41·04	39·06	45·12	45·34	43·39	45·50	42·96	41·60	41·49	45·96	40·21
	Reference-point temperature, ° C.	320	350	390	375	415	450	400	445	425	385	355	378	375	367	365	400	324	350
30	Heat gain by mould, cal./g. of steel	52·12	50·05	50·85	54·31	52·25	48·56	46·52	49·08	45·18	54·63	52·79	52·45	54·30	51·11	49·89	47·80	53·86	49·95
	Convection and radiation loss, ,, ,,	2·12	1·82	2·49	2·06	2·40	2·90	2·30	3·02	2·60	1·88	1·89	1·89	1·92	1·65	1·72	1·88	1·99	1·62
	Heat loss from steel, ,, ,,	54·24	51·87	54·34	56·37	54·65	51·46	48·82	52·10	47·78	56·51	54·68	54·34	56·22	52·76	51·61	49·68	55·85	51·57
	Reference-point temperature, ° C.	410	440	475	460	490	500	475	520	485	490	470	468	455	455	457	460	414	425
40	Heat gain by mould, cal./g. of steel	59·82	58·00	58·07	62·39	60·55	55·87	54·27	56·78	52·80	62·54	59·38	60·67	62·46	58·43	58·65	55·95	59·76	...
	Convection and radiation loss, ,, ,,	3·85	3·21	4·21	3·58	4·04	4·77	3·99	4·82	4·19	3·36	3·28	3·34	3·33	2·91	3·11	3·20	3·30	2·86
	Heat loss from steel, ,, ,,	63·67	61·21	62·28	65·97	64·59	60·64	58·26	61·60	56·99	65·90	62·66	64·01	65·79	61·34	61·76	59·15	63·06	...
	Reference-point temperature, ° C.	465	485	540	525	550	550	525	570	540	550	510	533	525	520	525	525	454	480
50	Heat gain by mould, cal./g. of steel	66·41	64·83	64·25	68·92	67·01	61·99	60·76	62·56	58·27	67·96	66·43	66·13	68·71	64·66	...	61·18	67·61	...
	Convection and radiation loss, ,, ,,	5·98	4·86	6·26	5·44	6·05	7·02	6·08	6·97	6·08	5·18	4·99	5·14	5·10	4·47	4·82	4·80	4·93	4·39
	Heat loss from steel, ,, ,,	72·39	69·69	70·51	74·36	73·06	69·01	66·84	69·53	64·35	73·14	71·42	71·27	73·81	69·13	...	65·98	72·54	...
	Reference-point temperature, ° C.	510	535	570	575	590	600	580	610	570	590	570	588	570	560	565	580	524	530
60	Heat gain by mould, cal./g. of steel	71·67	70·69	69·56	74·08	72·88	67·07	65·51	67·05	64·47	72·41	...	70·67	73·48	69·49	...	65·77	72·50	...
	Convection and radiation loss, ,, ,,	8·56	6·81	8·65	7·59	8·38	9·60	8·49	9·42	8·30	7·32	...	7·27	7·18	6·29	6·76	6·61	6·94	6·17
	Heat loss from steel, ,, ,,	80·23	77·50	78·20	81·67	81·26	76·67	74·00	76·47	72·77	79·73	...	77·94	80·66	75·78	...	72·38	79·44	...
	Reference-point temperature, ° C.	545	570	605	605	625	640	605	635	605	620	...	618	605	600	600	570	549	565
80	Heat gain by mould, cal./g. of steel	79·05	80·62	79·44	83·23	82·74	...	73·63	77·71	73·38	78·56	...	76·17	79·68	75·79	75·28	...	78·59	73·21
	Convection and radiation loss, ,, ,,	14·98	11·60	14·28	12·58	13·79	...	13·91	15·11	13·47	12·30	...	12·19	11·98	10·60	11·35	...	11·63	12·24
	Heat loss from steel, ,, ,,	94·03	92·22	93·72	95·81	96·53	...	87·54	92·82	86·85	90·86	...	88·36	91·66	86·39	86·63	...	90·22	85·45
	Reference-point temperature, ° C.	595	615	650	645	665	...	630	680	650	670	...	643	650	650	625	...	584	600

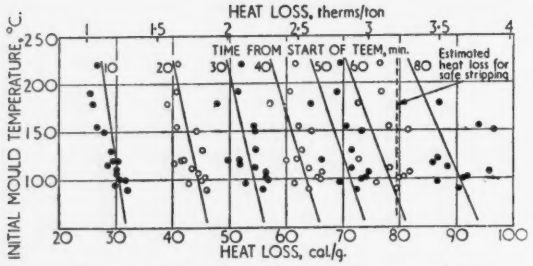

HEAT LOSS, therms/ton
TIME FROM START OF TEEM, min.
Estimated heat loss for safe stripping
INITIAL MOULD TEMPERATURE, °C.
HEAT LOSS, cal/g.

Fig. 3—Effect of initial mould temperature on heat loss from mid-height slice of steel

varies with mould temperature, but it is considered that its greater simplicity gives it greater application. A graph showing the relationship is given in Fig. 3, and its practical application is discussed later.

In these analyses, trials 7, 8, and 13, in which the mould was isolated or in an end position, were omitted because convection and radiation losses had to be calculated on a different basis from the rest.

These equations are also only applicable for times up to 80 min. from start of teem. Owing to stripping, insufficient data are available for further analysis, and, in any case, since radiation and convection from the mould surface are the principal factors in the heat loss from the ingot after this time, an experimental rather than a calculated estimate of this loss is required.

Correlation with Mould Surface Temperature as the Main Variable

The experimental technique using 40 thermocouples inserted into the walls of an ingot mould has several disadvantages, and in a previous paper[1] it was shown that there was a correlation between the heat loss of the ingot and the temperature of the mould outer surface at a single reference point. This point is at the centre of the long face adjacent to the pit wall.

An analysis has now been made relating the heat gain by the mould and the calculated heat loss by radiation and convection from the surface with the temperature at the reference point and the initial mould temperature. This resulted in the following relationships:

$$H_m = 0{\cdot}1120_s - 0{\cdot}1090_m + 15{\cdot}0 \text{ cal./g. of steel}$$
or $(0{\cdot}004520_s - 0{\cdot}0043900_m + 0{\cdot}605)$ therms/ton of steel;

$$H_{rc} = \text{antilog}_{10}(0{\cdot}0039400_s - 0{\cdot}0009700_m - 1{\cdot}366) \text{ cal./g. of steel}$$
or $\text{antilog}_{10}(0{\cdot}0039400_s - 0{\cdot}0009700_m - 2{\cdot}764)$ therms/ton of steel.

These relationships appear to hold until the heat loss from the steel, which is $H_m + H_{rc}$, reaches 75 cal./g. (3 therms/ton), a condition usually attained 60–80 min. from start of teem. After this, the rate of heat gain by the mould decreases rapidly and then begins to fall, the major heat loss being by radiation and convection. Owing to stripping, data have not yet been obtained to establish the formula when these conditions are reached. A graph showing the relationship is given in Fig. 4.

During trials 17–25, temperatures were taken at the reference point of six other moulds. Only slight variations in temperature were found, and, on applying the above equation, it was found that there were no significant differences in the heat loss from

Table III

SUMMARY OF CONDITIONS FOR TEST MOULD

Trial No.*	Cast No.	Date of Tap	Time of Tap	Time from Tap to Teem, min.	Time from Teem to Strip, min.	Initial Mould Temp., °C.	Steel Temp., °C.		Position of Mould in Pit (see Fig. 2)	Remarks†
							Furnace	Mould		
7	L.693	7.1.51	9.30 p.m.	17	214	20	1592	1525	12	Cold pit and isolated mould
8	L.695	8.1.51	7.40 p.m.	20½	126	80	1580	1518	7	End mould
9	L.696	9.1.51	7.40 a.m.	14	94	155	1580	1529	5	
10	L.697	9.1.51	9.00 p.m.	9	96	107	1608	1530	3	
11	L.698	10.1.51	8.20 a.m.	8	102	150	1600	1533	3	
12	L.699	10.1.51	6.17 p.m.	14½	74	191	1592	1523	5	
13	L.700	11.1.51	3.45 a.m.	17	177	164	1584	...	7	End mould
14	L.701	11.1.51	2.50 p.m.	7½	118	220	1590	1531	1	
15	L.702	12.1.51	1.35 a.m.	10	146	179	1587	1552	6	Slagged ingot that 'blew' and was hard to strip
16	T.762	14.10.51	9.49 p.m.	17½	143	20	1582	1545	7	Cold pit and end mould
17	T.763	15.10.51	12.00 noon	12	161	100	1599	...	5	Killed steel
18	T.764	16.10.51	1.45 a.m.	9	66	130	1590	1522	3	
19	T.765	16.10.51	2.55 p.m.	12	110	111	1593	...	5	Killed steel
20	T.766	17.10.51	5.41 a.m.	13	132	101	1573	1520	6	
21	T.767	17.10.51	7.31 p.m.	8	152	96	1603	1530	4	
22	T.768	18.10.51	8.55 a.m.	8½	95	120	1580	1516	5	2½-in. nozzle; ingot hard to strip
23	T.769	18.10.51	11.18 p.m.	8	122	120	1580	1522	4	2½-in. nozzle
24	T.770	19.10.51	1.21 p.m.	7	114	89	1598	1530	3	2½-in. nozzle
25	T.771	20.10.51	1.37 a.m.	5	63	116	1598	1523	2	2½-in. nozzle

* Trials 1–6 previously reported[3, 4]
Trials 7–15: 1st series[1]
Trials 16–25: 2nd series
† Except where noted, all trials made with rimming steel, 1½-in. nozzles, and test mould surrounded by hot moulds

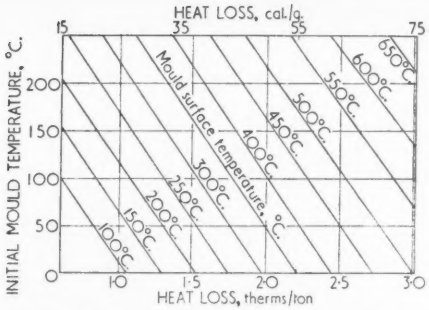


Fig. 4—Relation of heat loss from mid-height slice of steel to mould surface temperature and initial temperature

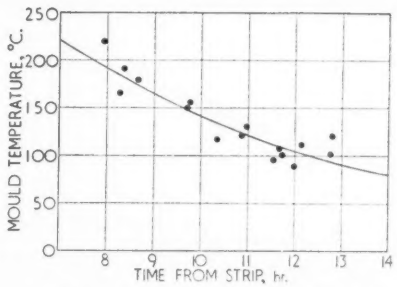


Fig. 5—Mould temperature at start of teem

the various ingots in the same cast dependent on the positions in which the moulds are normally placed.

Comparing the differences between the experimental results and those resulting from the deduced equation, it was found that the equation involving time as the variable was slightly better than that involving surface temperature.

Two casts in the second series were of killed steel. In these, the total heat lost was appreciably greater than in the case of the rimming steels, but, owing to the greater density, the heat loss per unit mass of steel conformed with the rest of the results.

The moulds were teemed in pairs with 1½-in. nozzles, requiring 2¾–3 min. to fill, including feeding, except in the last four trials, when 2½-in. nozzles were used and the moulds were filled in 1¾–2¼ min. No effect of these differences on the heat loss has been detected.

ESTIMATION OF INITIAL TEMPERATURE OF MOULD

As it is not yet possible to ascertain the initial mould temperature required in the above equation with sufficient accuracy, except by using fixed thermocouples, an attempt has been made to establish an empirical rule relating this temperature to the time since the previous strip. For the type of practice considered, when the moulds are merely left on the bank until reset in the pit, and one set of moulds is normally used for one furnace, this time is rarely less than 6 hr., and it has been assumed that from this time onwards the temperature is an exponential function of time. On this basis, the relation between the initial mould temperature, given in Table III, and the corresponding intervals between stripping and teeming, is

$$\theta_m = 629 \cdot 5e^{-0 \cdot 149t'}$$

and is illustrated in Fig. 5.

ESTIMATION OF SOLIDIFICATION RATE OF STEEL

Examination of horizontal sections of rimming steel ingots[9] shows that the contour of the rim closely conforms to that of the ingot, which, in the case of the slabbing ingots studied, approximates to a rectangle. It has been shown in the previous paper[1] that, assuming rectangular isotherms and a parabolic temperature distribution from the surface to the solidus isotherm, the distance from the surface solidified with the steel initially at the melting point can be estimated from the total heat lost and the temperature at the surface of the ingot by the equation

$$s^2\left[L + \frac{c(\theta_1 - \theta_0)}{6}\right] - s\,(a+b)\left[L + c\frac{(\theta_1 - \theta_0)}{3}\right] + \frac{Q}{4\rho} = 0$$

The density at 15° C. has been taken because the linear dimensions refer to those of a cold ingot.

The temperature of the ingot surface θ_0 has been calculated from the measured average temperature on the inner mould surface θ_s' and the instantaneous net heat flux by radiation by the formula

$$\sigma(\theta_0 + 273)^4 = \frac{F_N}{\epsilon} + \sigma(\theta_s' + 273)^4$$

The instantaneous net heat flux F_N is related to the heat loss from the steel by

$$F_N = \frac{1}{60} \cdot \frac{M}{P} \cdot \frac{dH_s}{dt}$$

The rate of change of heat loss from the steel can be calculated from the incremental changes over the time intervals used, or alternatively, since it has been shown that the heat loss is very nearly linear with the square root of time, by differentiating the appropriate equation $H_s = a\sqrt{t}$, giving

$$F_N = \frac{M}{60P} \cdot \frac{a}{2\sqrt{t}}$$

An example worked by these methods, using the average results of trials 17–25, is shown in Table IV. Although the steel in the ladle had an average of 30° C. superheat, measurements with dip thermocouples in the mould showed that this superheat was removed almost instantaneously, and it is reasonable to assume that the steel in the mould was never

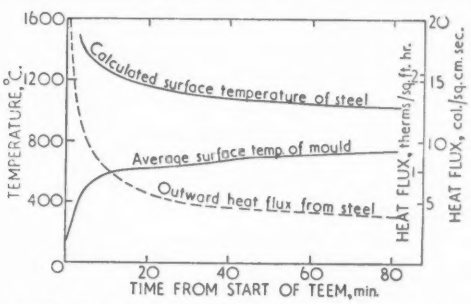


Fig. 6—Surface temperature of ingot and mould, and outward heat flux from steel (average of trials 17–25)

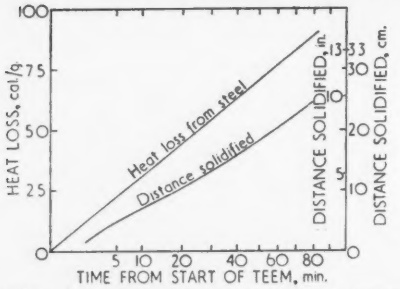


Fig. 7—Heat loss and distance solidified (average of trials 17–25)

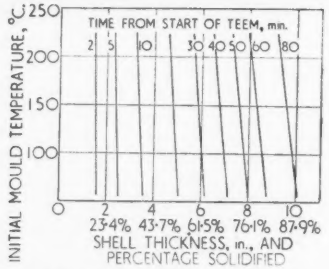


Fig. 8—Effect of initial mould temperatures on solidification of mid-height slice of steel

effectively above the liquidus temperature of 1530° C. The superheat has therefore been deducted from the total heat lost by the steel to obtain the value of Q for use in the solidification equation.

The results given in Table IV and Figs. 6 and 7 show that during the first 3 min. the outward heat flux from the steel is greater than can be accounted for by radiation alone, and must therefore be augmented by conduction.

The distance solidified in each trial has also been calculated separately, and, as in the case of heat lost by the steel, attempts have been made to represent it approximately as a simple function of time and to assess the effects of the uncontrolled variables. It has also been found that the distance solidified varies with the square root of time, that the initial mould temperature has a considerable effect of high significance, and that the initial steel temperature has a small effect of low significance. The equation expressing the relationship is

$$s = (2{\cdot}946 - 0{\cdot}00160\theta_m)\sqrt{t} \text{ cm.}$$
$$\text{or } s = (1{\cdot}16 - 0{\cdot}00060_m)\sqrt{t} \text{ in.}$$

and is illustrated in Fig. 8.

The average temperature distribution in the mid-height section in trials 17–25 obtained from direct measurements in the mould wall and by calculation in the steel is shown in Fig. 9. The calculated surface temperatures of the steel are very close to those obtained by optical pyrometer at the moment of stripping.

APPLICATION TO WORKS PRACTICE

Although the heat loss per ton from the mid-height section of the ingot will be less than that from the ingot as a whole, the differences between ingots should be comparable with the differences between their mid-height sections, so that these can be used as criteria for works practice.

It has been found by experience at this works that all 8-ton rimming-steel slabbing ingots can be safely stripped 75 min. after start of teem. The smallest heat loss from the mid-height section at this time is 3·2 therms/ton when the mould is initially at 220° C., and it is reasonable to suppose that all ingots can be safely stripped after losing this quantity of heat. This 'minimum' heat loss is shown by the vertical line in Fig. 3, suggesting that ingots teemed into cool moulds can be stripped up to 20 min. earlier than the empirical 75 min.; in Fig. 10, the minimum time for stripping is plotted against the time from previous

Table IV

METHOD OF CALCULATION OF THICKNESS OF SOLIDIFIED SHELL (MEAN OF TRIALS 17 TO 25)

Time from Start of Teem, min.	2	3	4	5	10	20	30	40	50	60	80
Heat loss from steel, cal./g.	14·0	17·0	19·8	22·1	29·8	43·4	53·5	62·8	70·7	77·3	87·8
Average inside surface temperature of mould, θ'_s, °C.	320	380	450	490	591	618	649	683	709	728	748
Instantaneous heat flux, cal./sq. cm. sec. $\left\{F_N = \frac{M}{60P}\cdot\frac{a}{2\sqrt{t}} = \frac{48{,}300}{60\times350}\times\frac{9{\cdot}42}{2\sqrt{t}} = \frac{10{\cdot}83}{\sqrt{t}}\right\}$	7·66	6·25	5·42	4·85	3·43	2·42	1·98	1·71	1·53	1·40	1·21
Outward flux from steel, cal./sq. cm. sec. $\rho(\theta_s+273)^4 = \frac{F_N}{\epsilon} + (\theta'_s+273)^4$	15·49	12·76	11·20	10·15	7·61	5·71	4·94	4·54	4·33	4·17	3·90
Average steel surface temperature θ_s, ° C.	1530	1478	1421	1380	1265	1158	1108	1078	1063	1050	1028
Temperature differential in steel (1530° − θ_s)	0	52	109	150	265	372	422	452	467	480	502
Coefficient of s^1 $L + c\frac{(\theta_1-\theta_s)}{6} = 65 + 0{\cdot}0067\ (1530-\theta_s)$	65·0	66·39	67·91	69·00	72·07	74·92	76·25	77·05	77·45	77·80	78·39
Coefficient of s $(a+b)\left[L + c\frac{(\theta_1-\theta_s)}{3}\right] = 5655 + 4{\cdot}64(1530-\theta_s)$	5655	5896	6161	6351	6885	7381	7613	7752	7822	7882	7984
Coefficient of s^0 $\frac{Q}{4\rho} = \frac{M(H_s - H'_s)}{4\rho} = 1{\cdot}81\times10^3\ (H_s - 5{\cdot}0)$	16,290	21,720	26,788	30,951	44,888	69,504	87,785	104,618	118,917	130,863	149,868
Thickness of shell s, cm.	3·2	3·5	4·3	4·9	7·1	10·3	13·0	15·8	18·3	20·6	24·4
" " " " in.	1·2	1·4	11·7	1·9	2·8	4·0	5·1	6·2	7·2	8·1	9·6

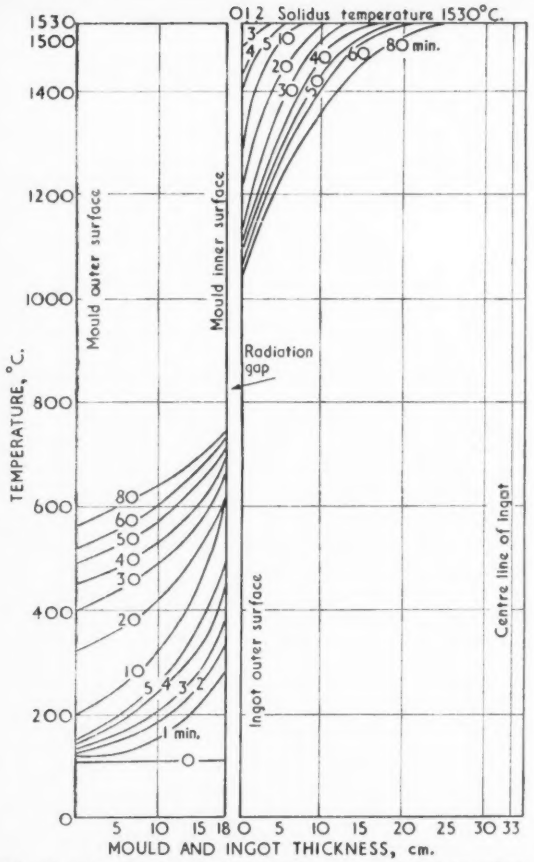


Fig. 9—Temperature distribution in mid-height slice of ingot and mould (average of trials 17–25); Values on curves show time from start of teem

strip to start of teem, which is related to initial mould temperature.

The total heat to be dissipated in reducing the heat content of the steel from teeming temperatures of 1560–1600° C. to rolling temperatures of 1250–1300° C. is about $4\frac{1}{2}$ therms/ton. The magnitude of the heat loss from the ingot between stripping and charging to the soaking pit will, it is hoped, be the subject of a later investigation, but it can be estimated that, during the 15–20 min. transfer time normally required in this type of casting-pit practice, it would be rather more than 1 therm/ton. In consequence, only the ingots with minimum heat loss in the mould will be charged to the pits at rolling heat, requiring merely sufficient time for temperature equalization, while all the others will be cooled below rolling heat and require many additional therms owing to low efficiency of heat transfer as well as longer heating time. Such ingots, however, could have been stripped earlier, as indicated in Figs. 3 and 10, so that they also could have been charged to the pits at rolling heat.

The implications of this work extend to the subsequent heating and soaking time in the pits, which at present are empirically related to the total track time.[10, 11] When ingot moulds vary over a wide range

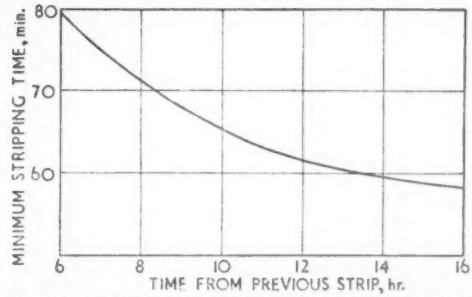


Fig. 10—Estimated minimum time for stripping

of initial temperatures, as has been found in this investigation, it would appear more reasonable to relate the heating time to the heat content of the steel as charged to the pits. If, for example, the empirical rule is

Minimum Heating Time = Track Time + 90 min.

this will be appropriate for the coldest ingots, *i.e.*, those teemed into moulds initially at atmospheric temperature; it is indicated by the top line in Fig. 11. Ingots teemed into moulds at higher temperatures, being hotter for the same track times, require less time for conditioning, as shown by the other lines in this figure; *e.g.*, the saving with a track time of 150 min. and a mould initially at 190° C. (teemed 8 hr. after previous strip) is 35 min.

It has been assumed in constructing Fig. 11 that the time between stripping and charging is the same in all cases, and that the results obtained up to 80 min. can be extrapolated to longer times.

These variations would not occur if all the moulds were always at the same initial temperature, and, if this was 20° C., the ingots could be stripped after 55 min., and, still following the empirical rule, would only require 145 min. heating time instead of the minimum of 165 min. required when stripping at 75 min.

It is generally appreciated that the thermal efficiency of a soaking pit as a reheating furnace is low, and that low fuel consumptions can only be obtained by

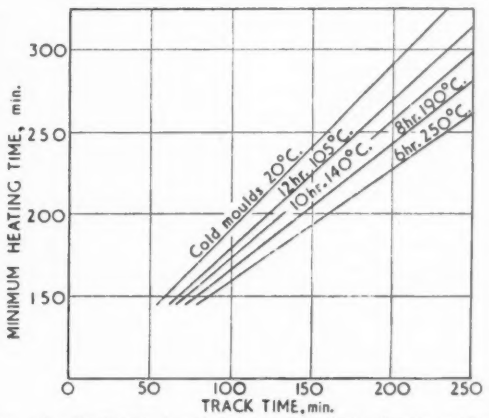


Fig. 11—Estimated minimum heating times; values on curves show temperature and time from previous strip

charging ingots with short track times, so that they already contain approximately the appropriate heat for rolling, and merely require time for conditioning to a uniform temperature. Under such conditions, the fuel requirements will be the amount necessary to offset heat losses from the pit itself, and will depend very largely on the condition of the structure and the waste-heat recovery equipment.

When ingots cannot be charged at the earliest moment, additional time and heat are required to bring them to rolling temperature. It is most important that this time should be kept to a minimum to avoid a self-aggravating system, for delay in drawing a charge may delay the charging of the next cast, thereby increasing its track time and subsequent heating time. The converse also holds: reducing the heating and soaking time increases the pit availability, and thus tends to decrease the subsequent track and heating times of the following cast.

CONCLUSIONS

The following conclusions are based on a horizontal mid-height section of a rimming-steel 8-ton slabbing ingot cooling in a mould in a casting pit, and assume that heat transfer perpendicular to the section is negligible.

The ingots are normally stripped within about 80 min. from the start of teem; insufficient data have been compiled for detailed analysis for longer periods. Conventional methods of statistical analysis have been used, and the chance of the conclusions being accidental is always less than 1 in 100, and usually less than 1 in 1000.

(1) Although the mechanism of heat loss from the mid-height section of an ingot is complex, it can be represented with sufficient accuracy for most industrial purposes as being proportional to a power function of time ($H_s = at^n$).

(2) The initial temperature of the ingot mould has a considerable effect on the heat loss from the steel. By introducing it as a linear correction factor, the equation for heat loss from the mid-height section can be written

$$H_s = (13{\cdot}097 - 0{\cdot}029066\theta_m)\sqrt{t}^{(0{\cdot}421 + 0{\cdot}00077\theta_m)} \text{ cal./g.}$$

or $(0{\cdot}528 - 0{\cdot}001170\theta_m)\sqrt{t}^{(0{\cdot}421 + 0{\cdot}00077\theta_m)}$ therms/ton.

(3) The exponent in the above equation does not vary widely from a value of 0·5, and, without serious additional error, the heat-loss equation can be simplified to

$$H_s = (11{\cdot}09 - 0{\cdot}00830\theta_m)\sqrt{t} \text{ cal./g.}$$

or $(0{\cdot}443 - 0{\cdot}000330\theta_m)\sqrt{t}$ therms/ton.

(4) The heat loss from the ingot section can be alternatively represented, independently of time, from the initial mould temperature and the subsequent temperature at a suitable reference point on the mould surface, by the summation of

Heat gain by mould
$= (0{\cdot}1120\theta_s - 0{\cdot}1090\theta_m + 15{\cdot}0)$ cal./g. of steel
or $(0{\cdot}004520\theta_s - 0{\cdot}004390\theta_m + 0{\cdot}605)$ therms/ton

Surface heat loss
$= \text{antilog}_{10}(0{\cdot}003940\theta_s - 0{\cdot}000970\theta_m - 1{\cdot}366)$ cal./g. of steel
or $\text{antilog}_{10}(0{\cdot}003940\theta_s + 0{\cdot}000970\theta_m - 2{\cdot}764)$ therms/ton

This is slightly less accurate than the relation depending on time.

(5) The initial mould temperatures can be estimated from the time interval between the previous strip and start of teem by

$$\theta_m = 629{\cdot}5e^{-0{\cdot}149t'}$$

(6) The thickness of the shell of the solidifying ingot can be adequately represented by the formula

$$s = (2{\cdot}946 - 0{\cdot}00160\theta_m)\sqrt{t} \text{ cm.}$$
or $(1{\cdot}16 - 0{\cdot}0060\theta_m)\sqrt{t}$ in.

(7) The data were inadequate to establish the effect on the heat loss of the ingot of the relatively small variation in initial teeming temperature of the steel.

(8) The normal position of the moulds in the casting pit does not appear to influence the rate of heat loss of the ingot.

(9) No significant differences were found in the heat loss between the two casts of killed steel and the remaining casts of rimming steel.

(10) Increasing the rate of teeming from 3 min. to 2 min. per ingot has no appreciable effect upon the heat loss of the ingot.

(11) Ingots teemed into moulds at 50–80° C. can be stripped about 15 min. earlier than those teemed into moulds at about 200° C., thus reducing the track time.

(12) Empirical heating times based on track time of ingots teemed into cold moulds can be reduced when the initial mould temperature is higher.

Acknowledgments

The authors express their thanks to the steelworks concerned for permission to undertake the work, to the management, staff, and operators of the melting shop, the casting bay, and the engineering department for their assistance in preparing the test moulds and carrying out the tests, and to the staff of the instrument section for the measurements of the liquid steel temperatures.

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PROCEEDINGS OF THE INSTITUTE

REPORTS OF COUNCIL - OFFICIAL NOTICES

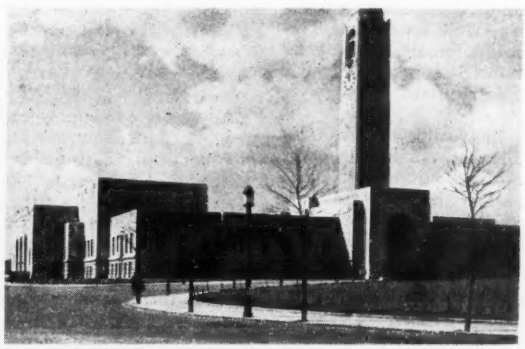
SPECIAL MEETING IN SWANSEA, 1952

A Special Meeting of The Iron and Steel Institute was held in Swansea from Tuesday, 7th, to Friday, 10th October, 1952, by invitation of the Mayor of Swansea, Councillor W. T. Mainwaring-Hughes, J.P. The Rt. Hon. Duncan Sandys, P.C., M.P., Minister of Supply, was the Chief Guest at a Luncheon following the official opening of the Trostre Works of the Steel Company of Wales, Ltd., on Tuesday, 7th October, 1952. A full programme of visits to works and excursions to places of interest was arranged for Members and Ladies.

RECEPTION COMMITTEE

UNDER the patronage of the Mayor of Swansea (Councillor W. T. Mainwaring-Hughes, J.P.), a Reception Committee and a Ladies Committee were formed to make the arrangements in South Wales. Colonel J. M. Bevan, M.C., D.L., J.P. (Briton Ferry Steel Co., Ltd.), was Chairman of the Reception Committee, and Sir Lewis Jones, J.P. (South Wales Siemens Steel Association), and Mr. P. O. Williams (Welsh Plate and Sheet Manufacturers' Association) acted as Joint Honorary Secretaries. Mrs. J. M. Bevan was Chairman of the Ladies Committee.

The Chairman and Board of Directors of the Steel Company of Wales, Ltd., issued an open invitation to Members of the Institute and their Ladies to visit the Trostre Works of the Tinplate Division on Tuesday, 7th October. Members and Ladies were able to take part in this visit whether or not they were attending the whole Meeting.



Guildhall, Swansea, with Brangwyn Hall at left

The President and Council of The Iron and Steel Institute wish to express their sincere thanks to the Mayor of Swansea, the Chairman and Members of the Reception Committee, and the Chairman and Members of the Ladies Committee; to the Chairman and Board of Directors of the Steel Company of Wales, Ltd., the South Wales Siemens Steel Association, and the Welsh Plate and Sheet Manufacturers' Association; to the Directors of the Works who kindly invited Members to visit them, and to all those who so helpfully collaborated in organizing the Meeting.

Owing to the limited amount of accommodation available, Members and Ladies stayed partly in the Swansea district and partly in Porthcawl.

The Council issued invitations to a number of Overseas Members and their Ladies to take part in the Meeting; many of these invitations were given to repay in a small degree some of the hospitality received during the three post-war overseas meetings held by the Institute in Switzerland (1947), Norway (1949), and Austria (1951).

A total of nearly 600 Members and Ladies attended the Meeting.

OPENING SESSION

The Meeting opened on Tuesday, 7th October, with the official opening of the Trostre Works of the Steel Company of Wales, Ltd. The Chief Guest was the Rt. Hon. Duncan Sandys, P.C., M.P., Minister of Supply. Members and Ladies, together with Guests of the Steel Company of Wales, were received by Mr. and Mrs. E. H. Lever and Sir Charles and Lady Bruce-Gardner.

A special train was run from London and back on 7th October for the convenience of those Members of the Institute and their Ladies and of guests of the Steel Company of Wales who joined the function at Trostre, but did not take part in the whole Meeting.

The official opening was followed by a Luncheon at

the Works, at which more than 1200 people were present. Mr. E. H. Lever (Chairman, Steel Company of Wales, Ltd.) was in the Chair. After the loyal toast, he proposed the toast of "The Minister of Supply." In doing so, he welcomed the Rt. Hon. Duncan Sandys and Mrs. Sandys and all those present, whether Members of The Iron and Steel Institute or guests of the Steel Company of Wales, and their Ladies. He particularly welcomed Mr. K. C. Gardner (President, United Engineering and Foundry Company) who had taken so prominent a part in the provision of the equipment from the United States for the Works.

He reviewed the social and economic background of the development of the Steel Company of Wales since the war and stressed the importance in these developments of the intimate co-operation that exists between both sides of the industry.

The Minister of Supply (Rt. Hon. Duncan Sandys), in reply, emphasized that the completion of the Trostre Works marked the second major stage in a bold and ambitious scheme of modernization and that with increasing competition from abroad the development of these highly efficient production units was essential. He gave an optimistic forecast of the future level of steel production and expressed satisfaction at the growing quantities of pig iron becoming available to replace the diminishing supplies of scrap.

Sir Charles Bruce-Gardner (Deputy Chairman, Steel Company of Wales, Ltd.) proposed the toast of "The Iron and Steel Institute" and stressed the part that it had played in the furthering of research and the dissemination of technical knowledge.

Captain H. Leighton Davies, C.B.E., President of The Iron and Steel Institute, replied. He said he was pleased and honoured that the meeting in Wales was being held during his period of Presidency. He thanked the Minister for being present and suggested that the overseas visitors could judge what an asset the Trostre Works would be to the industries of South Wales. He referred to the good results obtained by the staff and concluded by saying "look back and give thanks, look forward and take courage."

After the Luncheon, Members and Ladies had an opportunity of touring the Works and were afterwards entertained to tea.

In the evening they were entertained by the Mayor of Swansea, Councillor W. T. Mainwaring-Hughes, J.P., at a Reception at the Brangwyn Hall, Swansea. The Mayor hoped that Members would remember 1952 as the eve of a time of prosperity for Swansea and South Wales. He also gave a brief history of the Brangwyn murals in the Hall.

Principal J. S. Fulton (Vice-Chancellor of the University of Wales) welcomed Members to Swansea on behalf of the University. Mr. James Mitchell, C.B.E., Hon. Treasurer, replied on behalf of the Institute.

A number of Welsh and English songs were sung by the Cymru Ladies Choir, under the direction of Mr. Walter Glyn.

VISITS AND EXCURSIONS

Wednesday, 8th October

Arrangements had been made for Members to visit the Margam Works of the Steel Company of Wales in the morning and for Members and Ladies to visit the Abbey Works in the afternoon. These arrangements had unfortunately to be cancelled at short notice; instead, Members visited the Llandarcy Refineries of the National Oil Refineries, Ltd. Members and Ladies were entertained by the Steel Company of Wales to a Luncheon in the Orangery of Margam Abbey, by kind permission of Mr. D. M. Evans Bevan. Mr. E. Julian Pode (Managing Director of the Steel Company of Wales, Ltd.) welcomed the guests and expressed the regret of his Company that the visits originally arranged for that day had not been possible. Sir John Duncanson replied on behalf of the Institute.

Members and Ladies had the afternoon free and were entertained in the evening by the South Wales Siemens Steel Association and the Welsh Plate and Sheet Manufacturers' Association to a Banquet and Dance at the Brangwyn Hall. Colonel J. M. Bevan was in the Chair and announced that Her Majesty the Queen had graciously consented to become Patron of the Institute. In proposing the toast of "The Iron and Steel Institute," he spoke of the pride of all those in South Wales in the Presidency of Captain H. Leighton Davies, who had done so much for local industry, and thanked the Corporation of Swansea for its gesture of invitation and for the use of the Civic Buildings. He alluded to the Institute's 1600 foreign members and to the contribution which had been made by the Institute to the advancement of technical knowledge.

Captain H. Leighton Davies, in reply, thanked the Associations for their hospitality and emphasized the fine work that they had done over a long period in the encouragement of the development of university education and research in South Wales; he felt it was natural that there should be in the area a warm feeling of welcome for The Iron and Steel Institute.

Sir Andrew McCance, F.R.S., Past-President, in proposing the toast of the "Visitors from Overseas," suggested that, perhaps more than any other industry, iron and steel was international and was carried on in all countries in much the same way. Scientific principles fortunately had no nationality "not at any rate on this side of the iron curtain; perhaps on the other side it is the lack of principle that has given nationality."

Mr. G. Schjelderup (Chairman of A/S Christiannia Spigerverk, Oslo) expressed the thanks of the visitors from overseas.

Thursday, 9th October

Members were able to visit the following:

Aluminium Wire and Cable Co., Ltd., Port Tennant
British Iron and Steel Research Association Laboratories, Sketty Hall
Imperial Chemical Industries, Ltd., Waunarlwydd
Metal Box Co., Ltd., Clydach
National Smelting Co., Ltd., Llansamlet
Steel Company of Wales, Ltd., King's Dock Works
University College of Swansea.

All-day excursions were arranged to Llanwrtyd Wells and the Black Mountains and to Tenby for Ladies; those Members not visiting the Works and those Ladies who preferred half-day excursions had the opportunity in the afternoon of visiting either the Gower Peninsula or the Vale of Glamorgan and St. Donat's Castle.

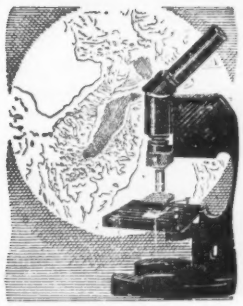
In the evening informal dances were held at Caswell Bay and at Porthcawl.

Friday, 10th October

The Meeting concluded on the morning of Friday, 10th October, but arrangements were made for a number of overseas visitors to visit Richard Thomas and Baldwins, Ltd., at Ebbw Vale, and Guest Keen Baldwins Iron and Steel Co., Ltd., and Guest Keen and Nettlefolds (South Wales) Ltd., at Cardiff.

All those who had the privilege of attending the meeting carried away with them a vivid impression of industrial enterprise and efficiency and lasting memories of the traditional Welsh hospitality.

The Effect of Hydrogen on the Tensile Properties of Steel



By
J. D. Hobson, B.Sc., F.R.I.C., and J. Hewitt, A.Met.

SYNOPSIS

The authors have further investigated the factors governing hydrogen embrittlement of steel. In addition to the influence of microstructure and heat-treatment, known from earlier work to be important, it is now shown that temperature and rate of testing are important variables. The relative immunity of austenitic steels to hydrogen embrittlement is confirmed, and the relationship between hydrogen embrittlement and diffusivity is considered. 722

In earlier papers,[1, 2] the authors described the results of their investigations into the effects of hydrogen on the tensile properties of low-alloy steels, and on the distribution of hydrogen in large masses of steel. The present paper gives details of further experiments on the effect of hydrogen on tensile properties; it is concerned with such variables as speed and temperature of testing, not mentioned in the earlier paper, and deals with some austenitic steels.

The main conclusion of the earlier paper[1] was that the previous heat-treatment of the sample was very important in determining the degree of hydrogen embrittlement. So long as this was taken into account, the ductility, as measured by percentage reduction in area in the tensile test, was found to decrease in a regular manner with increasing hydrogen content. With forged steel, the direction of the flow structure in the specimen must also be considered.

The methods of hydrogenation, using a high-pressure heating technique, and of hydrogen determination by vacuum-heating have already been fully described.[1] The analyses of all the steels used in the present investigation are given in Table I.

If the discontinuity-migration theory of hydrogen embrittlement, which involves the movement of atomic hydrogen by diffusion to discontinuities in the crystal structure during deformation, is accepted, it is assumed that molecular hydrogen accumulates in the micro-cavities and, by building up a pressure, leads to tri-axial stresses, causing failure at external stresses lower than in the absence of hydrogen. If the theory is correct, it should therefore be possible to avoid embrittlement resulting from the presence of hydrogen by testing at high speeds or at low temperatures, either of which would minimize the deleterious results of hydrogen migration. Both conditions have been tested experimentally, and the results obtained are described in the following sections.

INFLUENCE OF RATE OF TESTING

The influence of testing speed on hydrogen embrittlement is mentioned by Carney, Chipman, and Grant,[3] but the original thesis of Savetsila,[4] whose data they quoted, has not so far been made available to the authors. Savetsila found that the ductility fell with increasing strain rate until at the minimum value a 'fish-eye' was produced; subsequent increases in strain rate produced a steady recovery of ductility until the original value was regained. Seabrook,

Manuscript first received 5th September, 1952, and in its final form on 30th October, 1952.

Mr. Hobson, who was at the Brown-Firth Research Laboratories while engaged on the work described in this paper, is now with Hadfields Ltd., and Mr. Hewitt is at the Brown-Firth Research Laboratories.

Table I

ANALYSES OF STEELS USED IN THE INVESTIGATIONS

Steel	C, %	Si, %	Mn, %	S, %	P, %	Ni, %	Cr, %	Mo, %	Sn, %	W, %
A	0·27	0·23	0·49	0·009	0·014	0·27	3·15	0·41	0·015	...
B	0·25	0·18	0·48	0·008	0·014	0·23	3·15	0·44	0·011	...
C	0·28	0·22	0·64	0·027	0·025	0·17	3·23	0·57	...	...
D	0·26	0·26	0·53	0·006	0·015	0·21	3·32	0·40	0·014	...
E	0·29	0·34	0·53	0·009	0·013	0·24	3·11	0·42	0·015	...
F	0·28	0·22	0·92	0·006	0·013	26·05	0·31	...	...	0·78
G	0·94	1·38	14·38	...	...	...	...	...	...	...
H	0·12	0·25	0·24	0·036	0·012	12·88	12·78	...	...	...
I	0·06	0·48	0·54	...	...	10·33	18·47	...	...	...
J	0·12	1·37	0·86	0·027	0·018	21·52	23·37	...	...	...
K	0·58	0·31	4·78	0·005	0·018	12·43	3·49	...	...	...
L	0·57	0·48	7·45	0·011	0·030	8·85	4·00	...	...	...

Table II

RESULTS OF MINIATURE TENSILE TESTS ON STEEL *A*

Hydrogen, ml./100 g.	Tensile Properties: Yield Point (Tons/sq. in.)	Tensile Properties: Maximum Stress (Tons/sq. in.)	Elongation, %	Red. in Area, %
(*a*) Fractured at Minimum Speed on Denison Machine (Speed = 0·05 in./min.: Time to fracture = 4–5 min.)				
0·7	48·0	55·0	26·7	74·0
0·7	45·0	55·2	26·5	73·8
4·2	48·1	54·5	24·0	59·5
5·9	49·4	54·1	18·6	45·0
6·2	50·5	56·5	17·3	43·0
7·6	50·0	55·6	9·3	35·0
9·7	48·7	55·5	20·0	40·0
(*b*) Fractured at Maximum Speed on Avery Machine (Speed = 4 in./min.: Time to fracture = 3–5 sec.)				
0·7	...	57·4	25·5	72·0
0·7	...	55·0	25·3	70·5
5·3	51·1	55·6	22·5	59·0
5·6	52·3	56·8	14·5	57·0
6·9	51·1	55·8	21·3	47·0
7·7	52·3	58·3	21·5	45·0
8·1	51·1	55·6	17·5	40·0

Hydrogen, ml./100 g.	Charpy Results: Swing	Charpy Results: Energy, ft.lb.	Elongation, %	Red. in Area, %
(*c*) Fractured on Charpy Impact Machine (Speed = 18·9 ft./sec.: Time to fracture = 0·0012 sec.)				
Nil	105°	74·6	20·0	74·0
0·7	103·6°	77·2	25·3	70·5
5·1	103·0°	78·4	24·0	65·5
6·6	104·5°	75·6	24·0	67·0
7·4	105·5°	73·6	20·0	66·0
10·2	104·5°	75·6	24·0	65·0

Grant, and Carney[5] mention a diminution of embrittlement at high strain rates, and Petch and Stables[6] have described a similar effect.

Tensile Tests with Varying Strain Rate

A survey of the testing facilities available showed that three speeds were readily available from existing machines:

(i) An Avery hydraulic machine with a maximum crosshead movement of 4 in./min.
(ii) A Denison screw-operated machine, with a minimum speed of $\frac{1}{20}$ in./min.
(iii) A Charpy impact testing machine, with the pendulum tapped to take a miniature test piece. At the bottom of the swing, one end of the test piece is arrested by an attached crossbar hitting a pair of fixed anvils. The tensile test piece is fractured by a blow of 216 ft.lb., delivered at an initial velocity of 18·88 ft./sec. Calculation shows the time of fracture of the test piece to be about 0·001 sec., and this has been confirmed by high-speed photography, giving a measured time of fracture of 0·0012 sec.

Serval trial showed that the miniature test pieces required by the Charpy machine could give test results comparable in accuracy with those obtained with the 0·505-in. dia. specimens normally used, provided that a point micrometer was used to measure the reduction in diameter at the neck.

Test pieces were made from 3% chromium–molybdenum steel *A*, hardened and tempered to give a maximum stress of 55 tons/sq. in. The test pieces had a gauge length of 0·75 in. on a 1-in. parallel of 0·206 in. dia. One series was tested on each machine after hydrogenation by the high-pressure method. The results obtained are given in Table II, and Fig. 1 shows hydrogen content plotted against reduction in area. Figure 1 reveals that the test pieces broken at 0·05 in./min. show the greatest embrittlement; those broken at 4 in./min. lie near the curve obtained on normal 0·505-in. dia. test pieces, and those broken at 18·9 ft./sec. are very little influenced by hydrogen.

In a further experiment, test pieces were broken by two blows of 50 ft.lb. or three blows of $33\frac{1}{3}$ ft.lb., with and without hydrogen. These gave results that fell between the single-blow Charpy tests and the slower Avery tests, as would be expected theoretically, since a second or two elapsed between blows. However, the lower-energy multiple blows also require a lower striking velocity, so that this secondary experiment is not conclusive. There is little doubt that hydrogen embrittlement is much less severe at fast testing rates than at normal speeds, and this is probably the reason for the observation, made in the earlier paper,[1] that hydrogen has little effect upon notched-bar impact tests of the Izod or Charpy type.

Notched-Bar and Slow-Bend Tests

If hydrogen migration is necessary to produce embrittlement, a bend test carried out slowly should be susceptible to hydrogen embrittlement. This deduction has been confirmed experimentally, using a test piece loaded centrally and supported at the

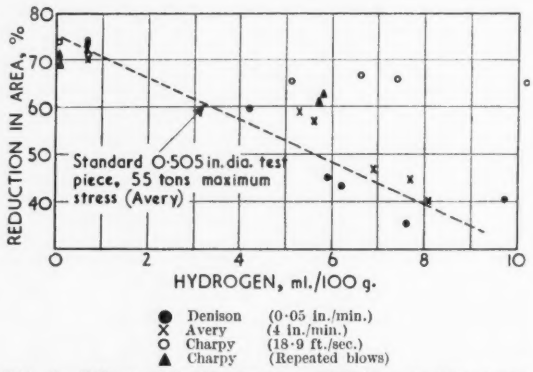


Fig. 1—Effect of hydrogen on miniature tensile tests at three different strain rates

Table III

EFFECT OF HYDROGEN ON SLOW-BEND TESTS

Test Piece	Hydrogen, ml./100 g.	Load to Fracture, tons	Angle of Bend at Failure
1. No notch	Trace	2·44	Unbroken at 57°
2. ,, ,,	1·1	2·50	28°
3. ,, ,,	2·4	1·84	7°
4. Notched	Trace	1·66	< 1°
5. ,, ,,	1·1	1·53	< 1°
6. ,, ,,	5·4	0·63	< 1°

ends, the load being applied with a tensile-testing machine.

The test pieces were $1\frac{1}{2}$-in. × $\frac{5}{16}$-in. dia. cylindrical bars, with hemispherical ends resting on supports 1 in. apart. These test pieces were either plain or with an Izod notch 1·5 mm. deep. They were machined from 3% chromium–molybdenum steel *A*, heat-treated to have a tensile strength of about 95 tons/sq. in. The results obtained are given in Table III.

These results show that in the case of a plain test piece, increasing hydrogen reduces the angle at which failure occurs. If a notch is present, the load needed to cause fracture is greatly lowered by the presence of hydrogen. This phenomenon is similar to the well-known hydrogen embrittlement of wire and sheet material in slow-bend tests.

The experimental results support the general statement that hydrogen embrittlement decreases with increasing speed of loading, either in tension or bend tests, Izod being included as fast-bend tests.

Other Mechanical Tests

Experiments were also carried out to ascertain the effect of hydrogen in torsion tests on 3% chromium–molybdenum steel *D*. Large test pieces of 0·625 in. dia. were loaded slowly, and small test pieces of 0·125 in. dia. were broken by impact from the momentum of a flywheel. No definite influence could be ascribed to the presence of hydrogen in either case.

The effect of hydrogen on miniature Wöhler fatigue tests, run at 6000 reversals per minute, was also studied. The stress was adjusted to cause failure in 10–20 min., so as to minimize the loss of hydrogen. It was found necessary to give the unhydrogenated test pieces a treatment similar to that given during high-pressure hydrogenation, but in a neutral atmosphere, so as to eliminate all experimental variables. The test pieces were produced from 3% chromium–molybdenum steel *E*, hardened and tempered to 55 tons maximum stress.

At a stress of ± 36 tons/sq. in., six specimens of mean hydrogen content 0·8 ml./100 g. gave 116,400–335,200 reversals (mean value 212,700). At the same stress, six specimens of mean hydrogen content 7·0 ml./100 g. gave 53,700–113,100 reversals (mean value 81,200). At ± 34 tons stress, similar hydrogenation lowered the mean number of reversals from 370,000 to 90,600.

Although caution is necessary in interpreting the fatigue-test results, it appears that hydrogen definitely lowers the number of stress reversals necessary to cause failure.

INFLUENCE OF TESTING TEMPERATURE

Method of Testing

Austenitic steels are known to be relatively insensitive to hydrogen embrittlement, and hydrogen diffusion in such steels is very slow at room temperature. These facts suggested that tests on ferritic steels carried out at low temperatures, where the value of hydrogen diffusivity would be similar to that in austenite at room temperature, might lead to immunity from embrittlement.

A study of work on hydrogen permeability[7, 8] and of the data of Bennek and Klotzbach[9] suggested

Table IV

EFFECT OF COOLING LIQUID ON TENSILE PROPERTIES

Temperature, °C.	Medium	Hydrogen, ml./100 g.	Tensile Properties			
			Yield Point (Tons/sq. in.)	Max. Stress (Tons/sq. in.)	Elongation, %	Red. in Area, %
20	Air	1·9	33·2	41·8	31·5	78·2
20	Water	1·4	32·3	41·0	34·0	78·0
20	Air	0·1	45·6	52·7	27·0	74·4
20	Water	0·2	47·8	54·8	30·0	74·9
20	Air	1·7	60·5	67·0	22·0	70·7
20	Water	1·0	59·7	66·3	22·5	70·8
20	Air	0·7	92·5	97·9	17·0	56·2
20	Water	0·2	...	99·0	17·0	57·3
100	Air	1·6	32·0	39·0	33·5	78·9
100	Water	1·2	30·8	38·5	34·0	78·9
100	Air	1·0	46·4	52·8	25·0	74·9
100	Water	0·3	43·5	49·2	28·5	76·3
100	Air	0·8	61·2	64·0	21·5	69·7
100	Water	1·9	58·4	63·0	22·0	71·2
100	Air	0·7	...	96·2	16·5	52·0
100	Water	0·4	93·5	96·0	17·0	53·4

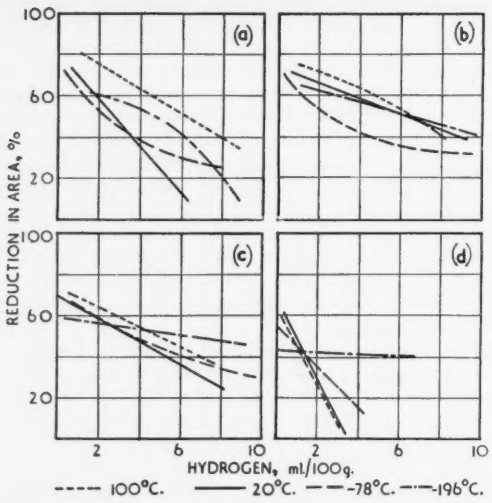


Fig. 2—Effect of testing temperature on hydrogen embrittlement of 3% Cr–Mo steel. Maximum stress (*a*) 41·5, (*b*) 53, (*c*) 67, and (*d*) 98 tons/sq. in.

that the diffusion in ferritic steels might be sufficiently low at about — 150° to — 200° C. A study was therefore made of the influence of testing temperature and hydrogen on the ductility of 3% chromium–molybdenum steel *B* at 100°, 20°, — 78° and — 196° C.; since the microstructure was already known to be an important variable, the steel was tested with four alternative heat-treatments. The rate of testing was standardized at the usual 4 in./min. given by the 40-ton hydraulic machine.

Since the heat generated during the test would alter the temperature of the test piece, it was deemed essential to carry out the tests in a liquid bath. The results at 20° and 100° C. were obtained in water, those at — 196° C. in boiling liquid nitrogen, and those at — 78° C. in a freezing mixture of crushed solid CO_2 and acetone.

A recent paper by Benedicks[10] has pointed out that the results of bend tests on various materials, including steel, are profoundly influenced by the presence of surface films of liquids, such as water, organic solvents, and grease; a preliminary set of experiments was therefore carried out to investigate the possibility of a similar disturbing variable in the tensile test. The results of this work are given in Table IV, from which it will be seen that at 20° and 100° C. the effect of water on the tensile test is no larger than might be expected from normal random error.

The main series of test pieces was then hydrogenated by the high-pressure method and tested at the appropriate temperature, hydrogen being determined by vacuum heating immediately afterwards. The temperature of the liquid bath was checked by a thermocouple, and the test piece was allowed several minutes to reach equilibrium at the required temperature. The results of the tensile tests and hydrogen determinations are given in Table V.

Experimental Results

Figure 2 is a composite diagram showing the variation of ductility (reduction in area) with hydrogen

Table V

EFFECT OF HYDROGEN AND TEMPERATURE OF TESTING ON DUCTILITY OF STEEL *C*

Testing Temperature and Medium	Hydrogen, ml./100 g.	Tensile Properties		Elongation, %	Red. in Area, %
		Yield Point	Max. Stress		
Series at 41·5 tons/sq. in. maximum stress					
Water, 100° C.	1·2	30·8	38·5	34·0	78·9
,,	3·9	...	38·5	30·5	65·6
,,	7·1	...	38·2	25·5	43·7
Air, 100° C.	1·6	32·0	39·0	33·5	78·9
Water, 20° C.	1·4	32·3	41·0	34·0	78·0
Air, 20° C.	1·9	32·2	41·8	31·5	78·2
Acetone, —78° C.	0·2	40·3	48·3	35·5	72·8
,,	3·7	43·0	49·5	24·0	38·5
,,	7·7	44·0	49·8	18·5	26·4
Nitrogen, —196° C.	1·0	73·3	73·3	27·0	64·2
,,	5·8	70·6	70·6	28·5	55·5
,,	8·4	71·3	71·3	14·0	13·8
,,	1·0	74·0	74·0	31·0	60·0
,,	3·8	74·0	74·0	30·5	56·0
,,	7·0	73·0	73·0	25·0	34·0
Series at 53 tons/sq. in. maximum stress					
Water, 100° C.	0·3	43·5	49·2	28·5	76·3
,,	4·3	44·2	50·6	22·0	62·2
,,	7·3	46·4	52·4	18·0	46·6
Air, 100° C.	1·0	46·4	52·8	25·0	74·9
Water, 20° C.	0·2	47·8	54·8	30·0	74·9
Air, 20° C.	0·1	45·6	52·7	27·0	74·4
Acetone, —78° C.	0·2	53·5	61·0	28·0	70·4
,,	3·7	52·0	60·6	21·5	39·8
,,	8·9	54·1	61·6	19·0	34·2
Nitrogen, —196° C.	2·4	81·1	82·6	25·0	61·0
,,	5·1	82·6	83·4	22·0	54·0
,,	8·9	80·5	80·5	25·0	44·2
Series at 67 tons/sq. in. maximum stress					
Water, 100° C.	1·9	58·4	63·0	22·0	71·2
,,	4·9	54·1	56·3	12·5	49·7
,,	7·4	57·7	61·3	13·0	39·0
Air, 100° C.	0·8	61·2	64·0	21·5	69·7
Water, 20° C.	1·0	59·7	66·3	22·5	70·8
Air, 20° C.	1·7	60·5	67·0	22·0	70·7
Acetone, —78° C.	0·6	65·3	71·5	25·0	68·8
,,	6·6	64·1	69·5	17·0	35·1
,,	9·5	64·9	70·2	12·5	31·9
Nitrogen, —196° C.	1·4	90·5	92·9	23·0	56·7
,,	5·0	89·6	92·5	21·0	51·9
,,	8·1	90·0	92·9	20·0	47·0
Series at 98 tons/sq. in. maximum stress					
Water, 100° C.	0·4	93·5	96·0	17·0	53·4
,,	2·2	...	93·0	11·5	29·2
,,	2·9	...	92·6	6·0	11·4
Air, 100° C.	0·7	...	96·2	16·5	52·0
Water, 20° C.	0·2	...	99·0	17·0	57·3
Air, 20° C.	0·7	92·5	97·9	17·0	56·2
Acetone, —78° C.	0·1	100·4	103·2	17·5	56·3
,,	2·9	...	100·8	11·5	27·6
,,	3·1	...	103·0	10·0	23·9
Nitrogen, —196° C.	0·7	...	120·5	16·0	43·0
,,	3·2	...	118·0	12·0	40·2
,,	5·0	...	119·0	14·5	42·3

and testing temperature for each of the four values of maximum stress used. The results at 20° C. have been taken from earlier work,[1] and so do not appear in detail in the Tables.

Figures 2 and 5 show that at 41·5 tons maximum stress hydrogen has its maximum effect at 20° C. and its minimum at 100° C. The results at — 78° C. are superior to those at 20° C. when the hydrogen is high. The results at — 196° C. are also superior to those at room temperature, but they are rather erratic. To produce this low value of maximum stress, 3% chromium–molybdenum steel requires prolonged tempering, and the microstructure shows pronounced spheroidization of the carbides. When tested at room temperature, hydrogenated specimens show a 'fish-roe' fracture, but this is much less evident in tests broken at — 196° C.

For the 53-ton series, hydrogen has a maximum effect at — 78° C., and there is little difference between the results at — 196°, 20°, and 100° C. If their initially lower ductility is taken into account, however, the tests at — 196° C. show least embrittlement by hydrogen.

At 67 tons maximum stress, the tests at — 196° C. are slightly less ductile than those at room temperature, but hydrogen is almost without effect on the ductility. The least ductile tests are obtained at 20° C., with a slight improvement at — 78° C. and marked superiority at 100° C.

With a maximum stress of 98 tons/sq. in. at 20° C., severe embrittlement results from quite small amounts of hydrogen, and similar results are obtained at 100° C. There is some improvement at — 78° C., and at — 196° C. hydrogen has little measurable effect. If the hydrogen content is above 1·5 ml. per 100 g., test pieces fractured at — 196° C. are superior to all the remainder in both ductility and maximum stress.

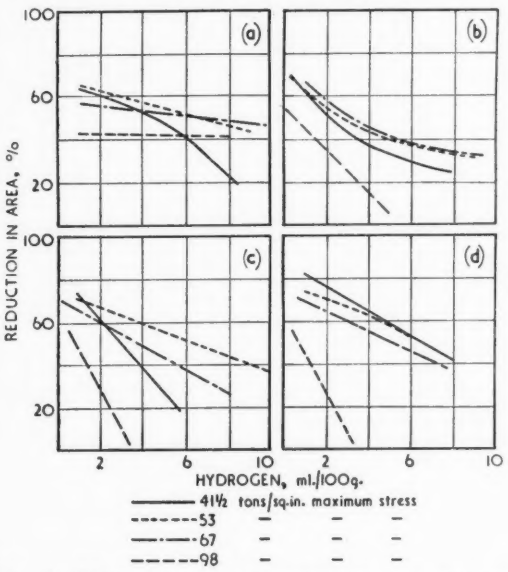


Fig. 3—Effect of testing temperature on optimum maximum stress for resisting hydrogen embrittlement of 3% Cr–Mo steel; (*a*) — 196°, (*b*) — 78°, (*c*) 20°, and (*d*) 100° C.

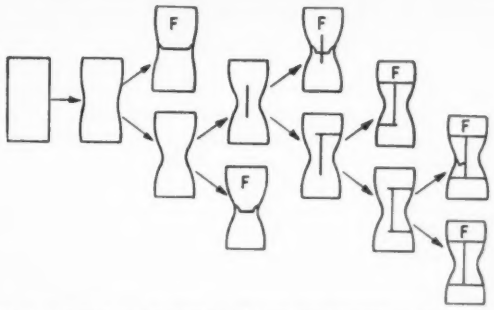


Fig. 4—Diagram of series of low-temperature fractures

Thus the general conclusion is reached that hydrogen is less deleterious at low temperatures than at room temperature, in accordance with theoretical expectations. It will also be observed that the stress, and presumably the microstructure also, that exhibits minimum sensitivity to hydrogen is a function of temperature. In general, it appears that lowering the testing temperature results in an increase of the stress at optimum resistance; this is more obvious from Fig. 3, where the data have been regrouped according to temperature to facilitate comparison.

Low-Temperature Fractures

Many of the test pieces broken at — 196° C. showed extraordinary fractures (*see* Fig. 5); Fig. 6 shows the appearance of the specimens fractured at —196° C. in more detail. The main features of the fractures were:

(i) Formation of a neck followed by a fracture some distance away
(ii) Formation of severe longitudinal splits
(iii) Formation of 1–3 small fragments in addition to the normal half tensiles.

Upon examination, these fractures seemed to be members of a series, and the probable sequence of events is shown diagrammatically in Fig. 4. Almost all the individual stages have actually been found in practice. Two main types may apparently occur at low temperatures. In one, the test piece breaks with a brittle fracture after very little reduction in area has occurred. In the other, a neck is formed, which then splits longitudinally; the two parallel semi-cylindrical and connected pieces so formed then break separately, usually at a distance from the original neck.

The presence or absence of hydrogen does not appear to contribute to this effect, which seems to depend solely on the ductility of the specimen. To check this deduction further, test pieces of 3% chromium–molybdenum steel *C* were made from blocks 6 in. × 1 in. × 1 in. cut from a large rotor forging in longitudinal, transverse, and radial directions. These were known to have differing ductilities when hardened and tempered to 55 tons maximum stress and tested at room temperature, owing to the varying flow structures produced in forging. When tested at — 196° C., the longitudinal specimens, being ductile, showed a 'neck and split' type of fracture, whether hydrogen was present or not, whereas the radial and transverse specimens gave a brittle fracture in either case.

Table VI summarizes the observations on the low-temperature work. These show that if the test piece had a reduction in area of 42·5% or less, the resultant fracture was always of the ' brittle ' type, but above 42·5% reduction in area, the fracture was always of the ' neck and split ' type shown in Figs. 4 and 6. The critical value on elongation lies between 14·5% and 16%, with one exception.

The mechanism of splitting and cracking out loose fragments seems to be associated with tri-axial stressed conditions, produced during necking. When testing at — 196° C., it was frequently observed that after the yield point ' drop ' the total load would only just rise to the same value again at maximum stress. Then either ' brittle ' fracture occurred at once, or the load fell back slowly, and then dropped sharply to about half value, and the test piece fractured. In the latter case, a ' neck and split ' fracture was invariably found, and it is thought that the sudden fall noted just before failure denoted the period when half the test piece was supporting the load. This theory is supported by measurements made on the minimum diameter of the loose fragment and corresponding main piece. In many cases, the fragment had a larger waist than the main test piece; it was never smaller. Thus, the main test piece must have continued to cold-work after the fragment had become detached, otherwise the neck measurement would be identical (*see* Table VI).

It is therefore concluded that during necking, tri-axial stresses are set up until a longitudinal split is formed, which relieves the radial stress at the neck but raises high stresses at the end of the split. Failure then occurs rapidly at one or both ends of the split, resulting in the types of fracture observed. Hydrogen is only important if it is present in sufficient concentration to prevent the ductility reaching 42·5% reduction in area, when ' brittle ' fracture occurs.

Tests at Very High Maximum Stress

To test the effect of very high stress, longitudinal specimens of 3% chromium–molybdenum steel *C* were oil-quenched after heating in either nitrogen or hydrogen at 900° C. The test pieces were then fractured at — 196° or 20° C.

At room temperature, the nitrogen-treated specimen gave 121·5 tons/sq. in. maximum stress and 28·9% reduction in area. The corresponding hydrogenated sample (3·7 ml./100 g.) fractured in the parallel at a load of only 6 tons/sq. in., and with no ductility. At — 196° C., the nitrogen-treated sample gave 97 tons/sq. in. maximum stress and fractured in the threaded head. The corresponding hydrogenated specimen fractured at 16·2 tons/sq. in. maximum stress, also in the head. If the effect of the thread in producing stress concentrations is neglected, these results are equivalent to 31·6 and 5·3 tons/sq. in. respectively on the area at the thread roots.

It is apparent that at high tensile strengths the steel is very susceptible to hydrogen embrittlement at room temperature, the maximum stress falling to one-twentieth of the normal value with less than

Table VI

TYPE OF FRACTURE OF TENSILE TEST PIECES BROKEN AT — 196° C.

Origin of Test Piece	Red. in Area, %	Hydrogen, ml./100 g.	Fracture Type*	No. of Extra Fragments	Neck Dia. on Fracture, in.†	
41·5 tons tensile (70 tons at — 196° C.)						
Bar (longitudinal)	64·2	1·0	NS	1	0·228	*0·242*
" "	55·5	5·8	NS	2	0·278	*0·281*
" "	13·8	8·4	B			
" "	59·2	1·5	NS	1	0·225	*0·228*
" "	36·8	5·8	B			
50–55 tons tensile (80 tons at — 196° C.)						
Bar (longitudinal)	61·0	2·4	NS	1		
" "	54·0	5·1	NS	1	0·285	*0·285*
" "	44·2	8·9	NS	2	0·289	*0·293*
Forging (longitudinal)	51·3	2·1	NS	1	0·283	*0·285*
" "	48·4	3·6	NS	1	0·283	*0·287*
Forging (radial)	5·5	0·5	B			
" "	3·7	8·0	B			
Forging (transverse)	1·7	1·4	B			
" "	0·4	6·8	B			
67 tons tensile (93 tons at — 196° C.)						
Bar (longitudinal)	56·7	1·4	NS	1	0·268	*0·281*
" "	51·9	5·0	NS			
" "	47·0	8·1	NS	2	0·305	*0·309*
98 tons tensile (120 tons at — 196° C.)						
Bar (longitudinal)	43·0	0·7	NS	3		
" "	40·2	3·2	B			
" "	42·3	5·0	B			

* NS = neck + split ; B = brittle † Values in italics refer to loose fragments

4 ml. of hydrogen per 100 g. At — 196° C., the steel also becomes very notch-sensitive, and this is emphasized in the presence of small amounts of hydrogen.

AUSTENITIC STEELS

Tests at Room Temperature

It is well known that austenitic steels are not liable to form hair-line cracks, and that they are not significantly embrittled by hydrogen. Tests have been carried out to investigate the effect of hydrogen on the tensile properties of several austenitic steels of different types, using material in the fully softened condition. Hydrogen can be introduced into the specimens by the usual high-pressure technique in most cases, provided that a much longer soaking time is given to allow for the much slower diffusion of hydrogen in austenite than in ferrite. In some cases, the hydrogenation must be carried out at about 350° C. to avoid austenite breakdown, which is liable to occur at higher temperatures, *e.g.*, in 13% manganese steel. In these cases, hydrogen may be introduced either by cathodic electrolysis or by heating the specimen in a furnace containing hydrogen at atmospheric pressure at about 1050° C., followed by water quenching to retain both the hydrogen and the austenitic structure. The solubility of hydrogen in austenite is about 3–4 times its value in ferrite at the same temperature, and so it is possible to introduce reasonable quantities of the element, either:

(i) At low temperatures and high pressure, or
(ii) At high temperatures and atmospheric pressure.

All these methods have been used, where appropriate, in investigating the hydrogen embrittlement of austenitic steels typical of those given in Table VII.

All these steels were found to be relatively uninfluenced by hydrogen, and in many cases large amounts of hydrogen, up to 25 ml. per 100 g., were needed to produce a measurable influence on ductility as measured from reduction in area in the tensile test. For this reason, the results are not given by the usual graphs; it is more convenient to calculate the change in percentage reduction in area for the addition of each millilitre of hydrogen per 100 grams.

Table VII summarizes the results obtained on austenitic steels. These results show clearly that the susceptibility of austenitic steels to hydrogen embrittlement is in most cases very small; even in the most unfavourable example it is only about one-third of that of the ferritic 3% chromium–molybdenum steel when the latter is heat-treated to have optimum resistance to embrittlement. The steels chosen have austenitic structures of very widely differing composition, and so it seems that their relative tolerance to hydrogen does not depend upon the presence of a particular alloying element, but is an intrinsic property of the austenite crystal lattice.

Effect of Hydrogen on Cold-Worked Austenite

Previous results having shown that the susceptibility to embrittlement of ferritic steels was closely related to maximum stress and microstructure, it was decided to attempt similar work on austenitic steels. Since these steels are not hardenable by heat treatment, the alternative is to raise the maximum stress by cold work; this was done by subjecting bars of two qualities to four stages of increasingly severe cold reduction by drawing suitable rod through dies. Tensile test pieces were then made from the cold-worked bars, and these were hydrogenated using the high-pressure technique at 360° C. It had been established by preliminary experiments that this temperature had no measurable effect upon the tensile properties.

The results are summarized in Table VIII; the final column shows that cold drawing renders both steels more susceptible to embrittlement by hydrogen than when in the fully softened state, and although the results are slightly erratic, there is no doubt that the effect increases in magnitude with increasing cold work. However, a comparison with the results in Table VII shows that the embrittlement is relatively slight, being only of the same order as that found for

Table VII

EFFECT OF HYDROGEN ON DUCTILITY OF AUSTENITIC STEELS AT ROOM TEMPERATURE

Steel	Type	Typical Tensile Properties (Hydrogen Absent)				Hydrogen Susceptibility: Change in Percentage Reduction in Area per 1 ml. Hydrogen/100 g.	Range of Hydrogen Content Tested, ml. Hydrogen/100 g.
		Yield Point (Tons/sq. in.)	Max. Stress (Tons/sq. in.)	Elongation, %	Red. in Area, %		
F	25% Ni	14	34	55	72	Nil	2–11
G	13% Mn, 1% C	29	70	68	40	Nil	1– 8
H	12% Cr, 12% Ni	20	38	67	75	Nil	0–13
I	18% Cr, 10% Ni	17	38	66	73	0·12	0–25
J	23% Cr, 21% Ni	33	46	46	59	0·47	0–13
K	3·5% Cr, 12·5% Ni, 5% Mn	21	45	80	75	0·90	0–25
L	4% Cr, 9% Ni, 7·5% Mn	20	43	78	67	1·25	0–27
D	3% Cr–Mo						
	at 94 tons/sq. in.	88	94	16	53	15	0– 4
	at 41 tons/sq. in.	32	41	32	76	13	0– 4
	at 51·5 tons/sq. in.	41	51·5	26	73	3	0–10

Table VIII

CHANGE OF DUCTILITY OF TWO AUSTENITIC STEELS WITH COLD-DRAWING AND HYDROGEN

Cold Reduction in Area, %	Typical Tensile Properties (No Hydrogen Present)				Hydrogen Susceptibility: Change in Percentage Reduction in Area per 1 ml. Hydrogen/100 g.	Range of Hydrogen Content, ml. Hydrogen/ 100 g.
	Yield Point (Tons/sq. in.)	Max. Stress (Tons/sq. in.)	Elongation, %	Red. in Area, %		
Steel H (12% Cr, 12% Ni)						
Nil	20	38	67	75	0·47	1–13
6·7	32	41	55	73	0·94	2–10
13·3	42	46	47	73	0·86	1–14
18·6	51	52	38	71	1·05	2–16
21·7	52	54	34	70	1·75	2–11
Steel J (23% Cr, 21% Ni)						
Nil	33	46	46	59	Nil	1–12
6·2	47	51	34	56	0·23	2–15
11·8	54	55	27	54	0·34	1–15
15·7	58	58	22	53	0·39	1–14
21·7	64	64	18	50	0·36	2–15

some other austenitic steels when fully softened, and much less than is found for ferritic steels in their most favourable condition.

Effect of Temperature

Although the diffusivity of hydrogen in austenite is very low at room temperature, it increases as the temperature is raised, and from the data available from the authors' measurements,[8] and those of Bennek and Klotzbach,[9] it appears that when the austenite is at about 500° C., it will be of the same order as in ferrite at room temperature. The comparison with ferrite is not exact, since hydrogen at this temperature will have a considerable solubility in austenite, whereas it is negligible in ferrite at room temperature.

Tensile test pieces made from 18% chromium–10% nickel steel *I* were tested at temperatures of — 78°, 20°, 100°, 300°, and 400° C., either after high-pressure hydrogenation or after vacuum degassing. The results obtained are given in Table IX.

A comparison of the ductility of hydrogenated and hydrogen-free specimens at any given temperature shows that embrittlement was only significant in the case of the test pieces broken at — 78° C.

It was also observed that the test pieces broken at — 78° C. were strongly magnetic after fracture, but those fractured at 100°, 300°, and 400° C. remained non-magnetic. When tested at 20° C., one test piece was afterwards found to be slightly magnetic and a second non-magnetic. The cold work during the tensile test apparently causes austenite breakdown at — 78° C., but not at 100° C. or above, and the room-temperature tests are on the borderline of instability. The breakdown ferrite produced at — 78° C. was visible on microscopic examination, and the hydrogen embrittlement found at — 78° C. was probably due to the action of hydrogen on this ferrite produced during cold working.

The rate of hydrogen diffusion is apparently not the sole cause of embrittlement, for the range of temperatures investigated would include a large variation of hydrogen diffusivity in austenite.

DISCUSSION AND CONCLUSIONS

Since the effect of hydrogen on ductility is reduced by testing at low temperatures, at high speeds, or with an austenitic structure, there seems to be a close

Table IX

HYDROGEN IMPREGNATION AND TENSILE TESTS OF AUSTENITIC TEST PIECES AT VARIOUS TEMPERATURES

Tensile Properties	Testing Temperatures				
	— 78° C.	20° C.	100° C.	300° C.	400° C.
Without hydrogen (vacuum degassed)					
Yield point, tons/sq. in.	...	16·7	15·0	11·5	12·5
Max. stress, tons/sq. in.	51·3	38·2	33·0	27·8	27·8
Elongation, %	48·5	66·0	54·5	46·0	45·0
Reduction in area, %	66·0	73·5	71·0	69·0	66·5
Hydrogenated					
Hydrogen, ml./100 g.	21·1	25·0	10·4	19·3	20·0
Yield point, tons/sq. in.	...	16·5	16·0	14·0	12·5
Max. stress, tons/sq. in.	51·0	37·5	32·5	27·8	28·0
Elongation, %	52·7	63·5	50·0	44·0	45·0
Reduction in area, %	46·0	70·5	71·5	66·0	66·0

Table X

HYDROGEN SOLUBILITY AT VARIOUS TEMPERATURES, ml./100 g.

	400° C.	500° C.	600° C.
Low-alloy steels by pressure method	0·34	0·68	1·08
Calculated Sieverts' data for pure iron	0·33	0·67	1·15

connection between hydrogen diffusivity, which is lowered in each case, and immunity from hydrogen embrittlement.

The true diffusivity can be calculated from measurements of solubility and permeability,[7] and the authors have found that for low-alloy steels the small alloy additions make little difference to the solubility. Using the high-pressure technique, the solubility in a number of low-alloy steels was determined, with no significant difference between the steels, and when corrected to one atmosphere pressure the results agreed well with Sieverts's values for pure iron[11] (*see* Table X).

The published data[8, 9, 12, 13] indicate that adding most alloying elements to iron reduces permeability, and the authors have found that it is susceptible to changes in microstructure.[8] It is therefore very probable that diffusivity also varies with structure, and this could be one factor involved in the interdependence of embrittlement susceptibility and microstructure.

In earlier work,[1] it was shown that tensile strength was a major factor in embrittlement, and, although it was recognized that microstructure was the underlying cause, the two variables were not clearly separated. This point was further investigated for 3% chromium–molybdenum steel, which was tested at various levels of maximum stress, each reached by alternative heat-treatments (*see* Table XI). It was found that both the ductility for hydrogen-free specimens and the rate of change of ductility with hydrogen content varied with type of microstructure as well as with maximum stress.

The main conclusion to be drawn from the results obtained on austenitic steels is that their immunity to embrittlement is a property of the γ-iron lattice, and is little altered by wide changes in alloy additions. Although the embrittlement was slightly increased by cold working, it never approached the magnitude found with ferritic steels in the least susceptible state.

The results presented in this and an earlier paper[1] make it apparent that hydrogen embrittlement is not so erratic a phenomenon as is usually envisaged, provided that all the related variables are controlled. The factors requiring consideration in experimental work on hydrogen embrittlement are:

Inherent in the steel:

(i) Hydrogen content
(ii) Alloy type (*i.e.*, austenitic or ferritic, and actua analysis)
(iii) Heat-treatment, microstructure, and tensile strength
(iv) Previous history of hot and/or cold working

Inherent in the mechanical test:

(v) Rate and type of testing (strain rate)
(vi) Temperature
(vii) Direction of stress.

With the quantities of hydrogen normally found in finished steel—say, 1–4 ml. per 100 g.—the effect on ductility at room temperature would not appear to be severe unless the steel is in either of two extreme conditions of treatment: either hardened and very lightly tempered, or very severely spheroidized.

The results make it obvious that hydrogen is not the only factor responsible for the formation of hair-line cracks, but that it needs association with transformation or cooling stresses, as other workers have also pointed out.

Acknowledgments

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(*cont'd on next page*)

Table XI

EFFECT OF HEAT-TREATMENT ON SUSCEPTIBILITY TO EMBRITTLEMENT OF 3% Cr–Mo STEEL *A*

Heat-Treatment (Austenitized 1 hr. at 900° C. in all cases)	Microstructure	Tensile Properties (Hydrogen Absent)		Embrittlement Susceptibility: Change in Percentage Reduction in Area per 1 ml. Hydrogen/100 g.
		Max. Stress, tons/sq. in.	Red. in Area, %	
Isothermal: 3 hr. at 720° C.	Ferrite + pearlite	40	58	5·2
Oil-quenched + 24 hr. at 720° C.	Spheroidized carbides	41	75	14·8
Isothermal: 1 hr. at 370°C. + 1 hr. at 700° C.	Tempered bainite	46	75	5·0
Oil-quenched + 2 hr. at 700° C.	Spheroidized carbides	47	75	7·0
Isothermal: 1 hr. at 370° C. + 1 hr. at 610° C.	Tempered bainite	62	64	5·0
Oil-quenched + 1 hr. at 580° C.	Tempered martensite	63·5	70	4·5
Isothermal: 1 hr. at 370° C.	Bainite	90	42	11·7
Oil-quenched + 1 hr. at 425° C.	Tempered martensite	94	63	11·6

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Transgranular Stress Corrosion in Chromium–Nickel Stainless Steels

By C. Edeleanu, M.A., Ph.D.

SYNOPSIS

The standard grades of austenitic stainless steels have been tested in a magnesium chloride solution. Those in which the austenite does not readily transform on straining have been found to be less susceptible to cracking. Experimental steels have confirmed that such failure can be largely avoided either by increasing the alloy content of the normal steels and thus making the austenite more stable, or by decreasing the alloy content and producing a partly martensitic steel in which the corrosion is less localized and therefore is less likely to cause cracking.

Transgranular stress corrosion has been obtained in many chloride solutions, including some relatively dilute, and there is evidence that oxidizing agents can cause an acceleration.

Metallographic evidence shows that a martensitic phase is produced on straining austenitic steels, and that this phase is corroded preferentially. 720

Introduction

ACCORDING to Sutton, Liddiard, Chalmers, and Champion,[1] the term 'stress corrosion' implies a greater deterioration in mechanical properties of a material through the simultaneous action of static stress and exposure to corrosive environment than would occur by the separate but additive action of these agencies. The phenomenon is a very general one and has been reported in most alloy systems. Similar effects are known to occur in glass, minerals, sugar, and plastics, and although the mechanism may differ from one case to another, it seems reasonable to expect similarities.

The most striking cases of stress corrosion are those in which an apparently brittle fracture occurs rapidly under conditions of stress and corrosion, either of which alone would cause insignificant damage. The amount of corrosion is very slight, and the cracking, although normally rapid once started, can be halted by chemical means.[2, 3]

Austenitic stainless steels can fail by a combination of intercrystalline corrosion and stress, but such intercrystalline failure is only likely under conditions which would, even in the absence of stress, give trouble. Intercrystalline corrosion, which has been extensively studied, is not discussed in the present paper, which deals only with the transcrystalline type of stress-corrosion failure.

The service failures examined in this laboratory have generally occurred in solutions containing chlorides at elevated temperatures, and have also occurred in impure steam. Similar failures have been reproduced in boiling concentrated chloride solutions,[4, 5, 6] and in ethyl chloride.[7] Boiling 42% $MgCl_2$ (b.p. 154° C.) is most widely used as a testing solution, and all usual grades of stainless steel crack when stressed in it.[8]

The stresses necessary for stress corrosion are reported to be low, both in practice and in laboratory experiments. For example, niobium-stabilized steels have been found to fail at 20% of their yield point, and one estimate of the threshold stress for this type of steel puts it below 10,000 lb./sq. in. and possibly as low as 3000 lb./sq. in.[8] Quenching stresses have been found to be sufficient for failure.[5]

Heat-treatment does not seem to affect stress corrosion appreciably. Material that shows susceptibility to intercrystalline corrosion in $CuSO_4/H_2SO_4$ solutions fails by transcrystalline cracking in chloride solution, both in practice and in the laboratory.[9, 10] The amount of branching of the cracks has been shown, however, to depend sometimes on the heat-treatment.[4]

Annealing temperatures above 840° C., followed by slow cooling,[6] are recommended to remove internal stresses, but welds between austenitic and ferritic steels cannot be effectively annealed.[7] Service failures of such assemblies are reported.[11]

The most interesting theoretical contribution from published work is the suggestion by Rocha and Tofaute that there is a connection between the α–γ transformation (taking place on straining austenitic

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Fig. 6—Unusual fractures in test pieces tested at −196° C., with hydrogen contents of (*a*) and (*b*) 5·8 ml. 100g. and (*c*) and (*d*) 1·0 ml. 100g. Both test pieces from steel with maximum stress of 41 tons/sq. in. at 20° C. (72 tons at −196° C.)

Fig. 5—Tensile test pieces for 41·5-ton series

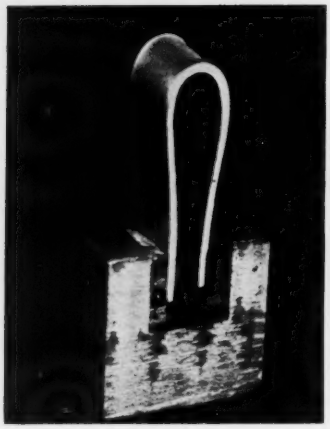
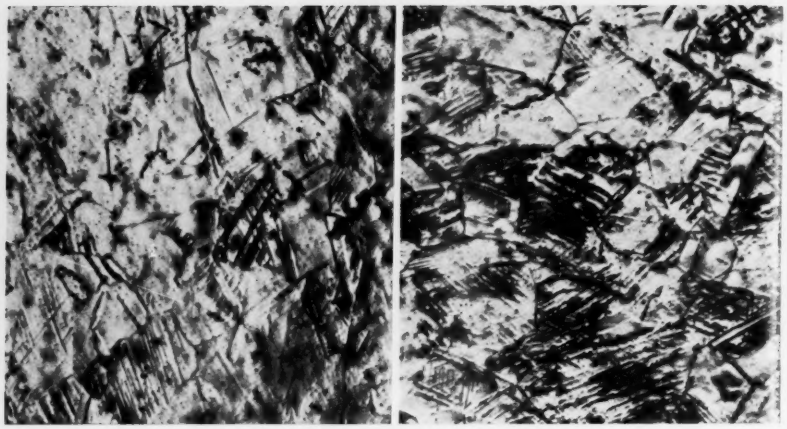


Fig. 1—Method of loading stress-corrosion specimens



(a) (b)

Fig. 2—Specimens of Cr–Ni steel, stressed 20%. Electropolished and etched. (*a*) 18·9% Cr, 8·9% Ni steel; (*b*) 18·0% Cr, 8·0% Ni steel × 250

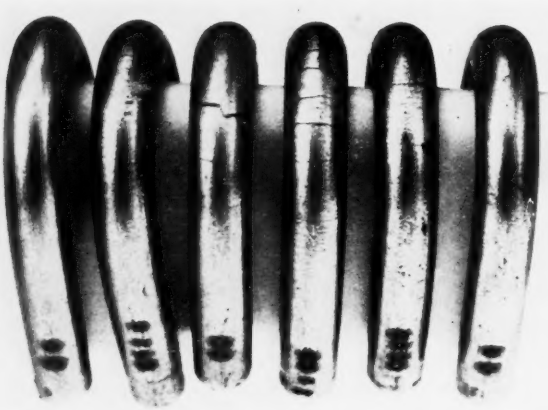


Fig. 3 — Titanium-stabilized steels with approximately 0·07% C, 18% Cr, and 0·5% Ti, containing (from left to right) 6·75%, 8·23%, 9·63%, 10·90%, 12·68%, and 13·93% Ni

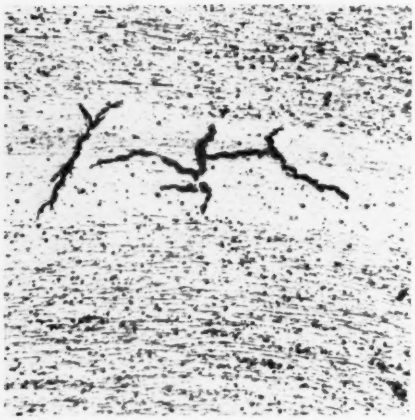
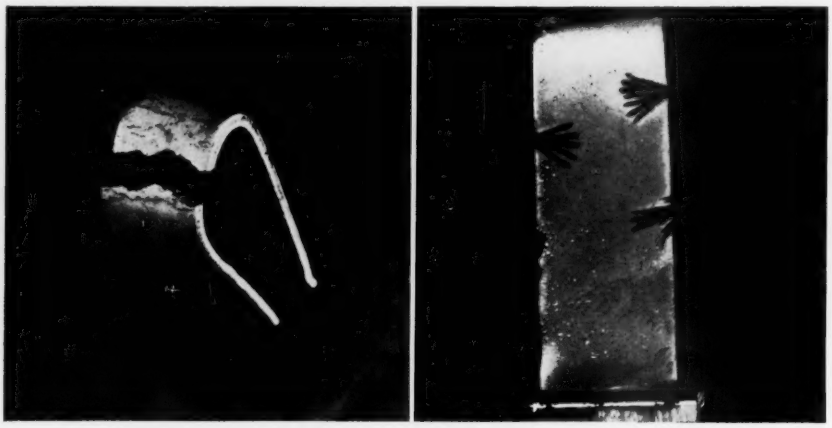


Fig. 4—Cracking confined to a central band in a segregated steel × 100

(a)



(b)

Fig. 5—Specimens cracked in (*a*) $MgCl_2$ solution; (*b*) 20% NaCl solution, showing 'fans'

(Figures 1, 3, and 5 are approximately actual size)

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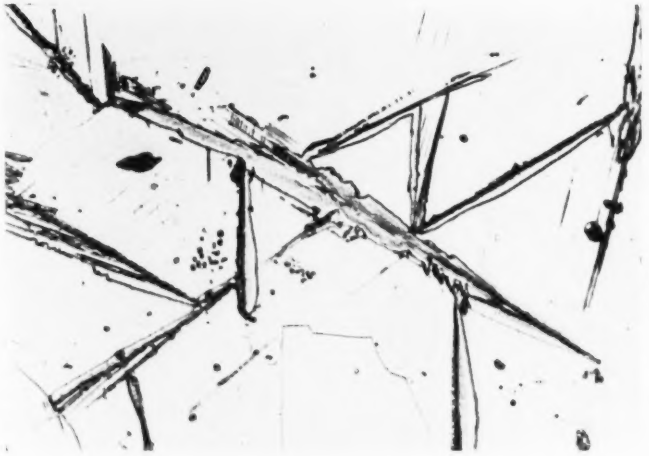
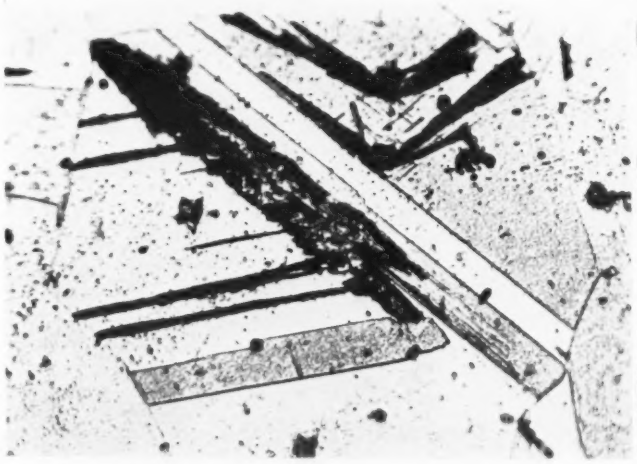
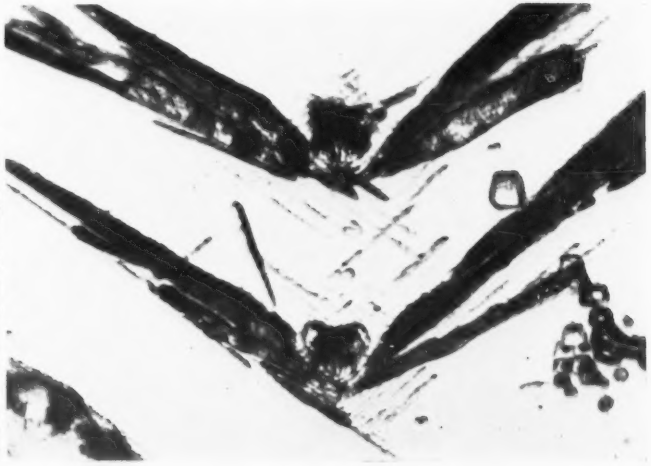


Fig. 6—Quasi-martensite formed in strained low-carbon 18/8 steel × 500

Fig. 7—Micro-hardness measurements on quasi-martensite and austenite, using 5-g. load. Unetched × 500



(a)



(b)

Fig. 8—As in Fig. 7, but after 8 hr. corrosion in $MgCl_2$ solution: (*a*) × 500; (*b*) part of field in (*a*) × 1500

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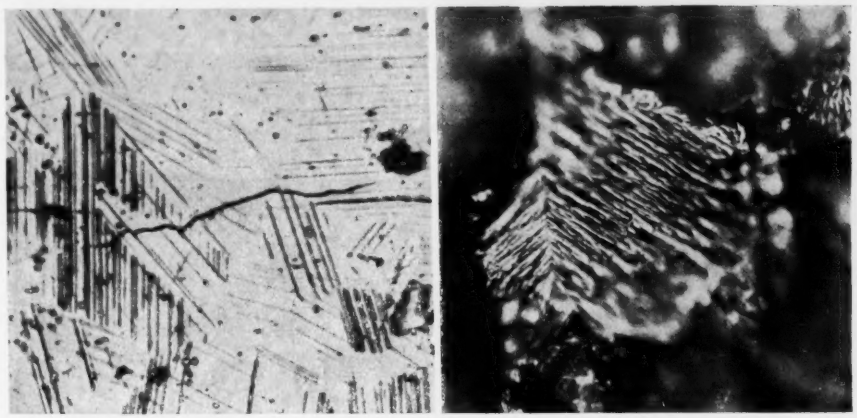

Fig. 9—Relationship between cracks and quasi-martensite: (*a*) Surface appearance of a crack in low-carbon 18/10 steel electropolished before testing × 1500; (*b*) fracture surface × 1000

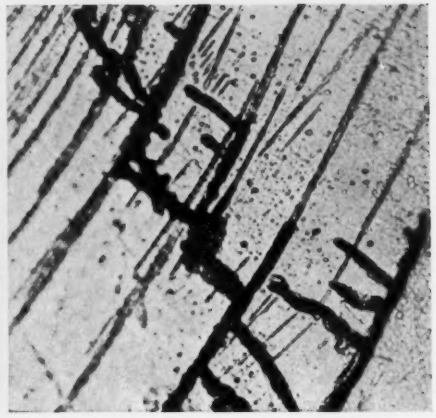

Fig. 10—Cracks and plates of quasi-martensite in an 8/4/8 Mn–Cr–Ni steel × 1000

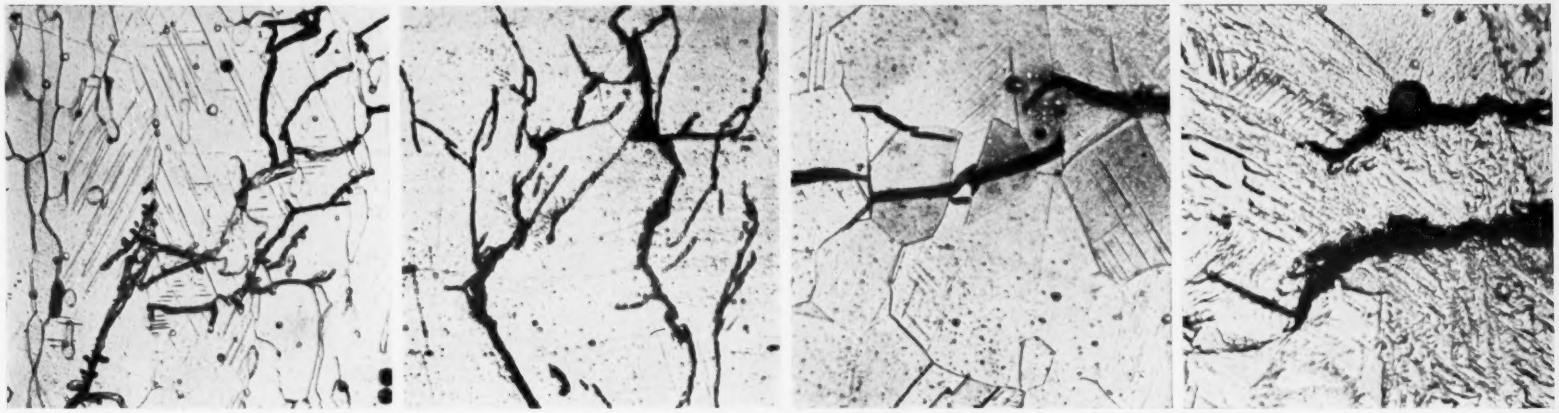

Fig. 11—Cracks in an 18/8 molybdenum steel which contained δ ferrite and a small quantity of quasi-martensite × 1000

(a) (b) (c)

Fig. 12—Stress-corrosion cracks: (*a*) in a normal 18/8 steel × 500; (*b*) in steel *B* (relatively stable austenite) × 500; (*c*) in steel *D* (containing large quantity of quasi-martensite) × 1000

steels) and stress corrosion.[12] This conception has been supported by Waber,[13] who has suggested that the stress corrosion of mild steel is also due to a phase change.[14] Waber's theory is not fully supported, however, by more recent work on mild steels.[15]

EXPERIMENTS IN CHLORIDE SOLUTIONS

Testing Method

Most of the present tests were carried out by bending 3 in. × ½ in. specimens, cut from 18-gauge material, into a U and then forcing the U into an 18/8 chromium–nickel steel holder so that an elastic stress was maintained (*see* Fig. 1). Glass slides on the side of the holder prevented electrical contact between holder and specimens. Specimens were bent by placing them on two rollers between which a plunger was forced so that a standard bend was obtained.

The austenitic steels were descaled in a nitric–hydrofluoric acid bath before testing, and the ferritic and martensitic steels were descaled in a dilute nitric–hydrochloric acid solution. Each test was carried out in approximately 200 ml. of solution, the specimen being totally immersed. In the longer tests the solution was changed whenever the boiling point had risen a few degrees owing to evaporation. The specimens were removed from the solution and were examined at intervals depending on the susceptibility of the steel.

The value of the stress in the bent specimens is not known, but it must be regarded as appreciably above the yield point. Although less obvious, the exact value of the stress from point to point is not known even in the conventional type of specimen loaded, for instance, by direct tension, since the distribution of the stress between the various grains and within each grain is unknown even before cracking has started. The main advantage of the bent-specimen type of test over the direct-tension test is the possibility of carrying out large numbers of experiments with simple equipment in a relatively short time.

The method gives surprisingly reproducible results with 18/8 types of steel, provided that the specimens are examined frequently enough. Electrical contact between different grades of steel must be avoided during testing, since it has been found that in certain solutions, including boiling 42% $MgCl_2$, cracking of 18/8 steels can be completely inhibited by coupling to plain chromium steels, containing either 17 or 20% of chromium, which are anodic to them. The cracking can also be accelerated by coupling to platinum. Electrolytic effects of this nature may be less important in steam or in many solutions used in practice, since they are only likely to occur to any appreciable extent in solutions having a high conductivity, and over relatively short distances.

Effect of Steel Composition

Tests were carried out on various steels in boiling 42% $MgCl_2$ solution (*see* Table I). The steels can be divided into three main groups: (i) steels based on the 18/8 composition, which are very susceptible to stress corrosion; (ii) steels with higher nickel contents, which are less susceptible and give somewhat scattered results; and (iii) ferritic and martensitic steels, which seem to be immune under the present conditions. Martensitic steels, however, are susceptible to other types of stress corrosion.[16, 17]

Tests on samples from various production casts of plain 18/8 steels have shown that the differences between various casts were slight, except in two cases in which lives of about 4 hr. were obtained instead of the more normal 2 hr. The chromium and nickel contents, in both cases, were rather high for this type of steel (18·92%, 8·90%, and 18·92%, 8·50%), and it was found by both magnetic and microscopic methods that cold work produced less breakdown of austenite in these steels than in the others (*see* Fig. 2).

Several experimental steels were made in which the chromium and nickel contents were varied; the results obtained are shown in Table II. Two of the experimental steels, *C* and *D*, transform very easily

Table I

STRESS CORROSION OF COMMERCIAL GRADES OF STAINLESS STEELS IN BOILING 42% $MgCl_2$ SOLUTION

Steel	Heat-Treatment, °C.	C, %	Si, %	Mn, %	Cr, %	Ni, %	Ti, %	Mo, %	Cu, %	Approximate Time to Failure (Based on 6 or more Tests)
18/8	A.C. 1050	0·08	0·60	0·74	18·62	8·03				2 hr. ⎫
Low carbon 18/10	A.C. 1050	0·05	0·43	0·82	18·44	9·75				2 hr. ⎬ ± 30 min.
18/8 Ti	A.C. 1050	0·10	0·69	0·94	18·04	9·58	0·61			2 hr. ⎭
18/8 Mo	A.C. 1050	0·06	0·29	0·75	17·88	8·33		2·78		2 hr.
12/12	A.C. 1050	0·07	0·32	0·69	12·62	11·58				8–15 hr.
25/20*	A.C. 1050	0·14	1·3	0·80	24·0	21·0				Shortest life 28 hr.; one not failed in 220 hr.
18/18 Mo, Cu	A.C. 1050	0·10	0·53	0·71	17·88	17·80	0·70	4·00	2·50	21–38 hr.
17/2*	A.C. 650	0·16	0·30	0·50	16·50	2·5				N.F.† in 500 hr.
20% Cr	W.Q. 800	0·06	0·60	0·76	21·50	0·19				N.F. in 1000 hr.
17% Cr	W.Q. 900	0·07	0·29	0·80	17·16	0·025				N.F. in 370 hr.‡
13% Cr*	A.C. 700	0·30	0·30	0·50	13·0					N.F. in 80 hr.‡
13% Cr	A.C. 750	0·19	0·22	0·29	13·72	0·64				N.F. in 120 hr.‡
13% Cr	A.C. 750	0·08	0·42	0·41	13·22	0·22				N.F. in 120 hr.‡

* Nominal composition † N.F. = Not failed ‡ Severe general corrosion

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Table II

STRESS CORROSION OF EXPERIMENTAL STEELS

Steel	C, %	Si, %	Mn, %	Cr, %	Ni, %	Time to Failure, hr.		
						A.C. 1050° C.	W.Q. 1050° C.	A.C. 1150° C.
A	0·14	0·70	0·34	17·34	14·00	72–88 287–303 303–310 359–383 149 N.F. 177 N.F.	31–95 120–136 500 N.F.	500 N.F.* 500 N.F. 500 N.F.
B	0·08	0·97	0·44	17·88	12·08	27–43 27–43 29–45 30–46 127–143 413–439	<16 29–45 0–64	<64 7–23 405–421
C	0·08	0·41	0·27	17·76	7·28	<17 <17 24–40 24–40 27–117 117 N.F.	26–56 426–442 500 N.F.	5–21 <64 457–473
D	0·07	0·80	0·48	15·32	8·05	500 N.F. 500 N.F. 500 N.F. 500 N.F. 500 N.F. 700 N.F.	287–303 342–368 500 N.F.	409–425 409–425 500 N.F.
E	0·08	0·90	0·47	19·82	8·15	5–21 27–43 55–71 77–167 356–372 447–462	30–47 96–118 264–280	6–22 60–87 287–303
F	0·07	0·84	0·47	15·27	11·98	<17 7–22 16–31 27–43 30–46 55–71	<64 5–69 26–117	<16 5–21 32–48
G	0·05	0·92	0·48	19·88	12·10	<17 3–19 6–22 26–30 44–45 350–414	<64 6–22 213–229	124–140 135–161 146–182

* N.F. = Not failed

on straining (especially the latter), whilst the austenite in the remainder of the steels is more stable than in the 18/8 type. Steel *E* is approximately 20/8 and contains some δ ferrite. All these experimental steels are comparatively resistant to stress corrosion. The results, like those for the high-nickel steels in Table I, show severe scatter under the present testing conditions. A number of other steels were made, based on the 18/8 composition, with additions of copper (2·08%), manganese (4·98%), and nitrogen (0·11%), but these additions did not cause any great change in stress-corrosion properties.

Various other steels, including some stabilized with titanium and niobium and others containing molybdenum, have also been tested, and the same general tendency as with the plain chromium–nickel steels was noticed. Figure 3 shows the appearance of some titanium-stabilized steels, containing about 18% of chromium and 6·75–13·93% of nickel, after boiling in the $MgCl_2$ solution for 7 hr. In this case the

Table III

STRESS CORROSION OF LOW-CARBON 18/10 STEEL IN BOILING CONCENTRATED CHLORIDE SOLUTIONS

Salt	Concentration, wt.-%	Type of Failure	Time, hr.
$ZnCl_2$	66	Broken	4–44
	50	Broken	53–64
	33	Small crack	200–265
NaCl	Saturated	Cracked (fans)	18
	20	Cracked (fans)	96
KCl	Saturated	Cracked (fans)	4–44
	33	Cracked (fans)	4–44
	26	Small crack	500–565
	20	Not cracked	440
LiCl	33	Small cracks	6–21
NH_4Cl	33	Cracked (fans)	28–44
$SnCl_2.2H_2O$	50	Not cracked	430
$NiCl_2.6H_2O$	25	Small cracks	79–143
$MnCl_2$	33	Small cracks	1216
$CaCl_2.2H_2O$	66 (approx.)	Broken	3·5–5·5
	50	Cracked	3·5
		Cracked (fans)	44
	27	Cracked (fans)	50–140
$CrCl_3$	25	Heavy general corrosion, no cracks	115
$HgCl_2$	25	Heavy general corrosion, no cracks	31

specimens, which were finished by grinding, were 5 in. long by $\frac{3}{8}$ in. dia. and were bent round a 1-in. dia. rod. The holders were made from the same steel as the specimen, so that the use of glass slides was unnecessary.

A titanium-stabilized 18·76% Cr, 9·33% Ni steel, in which there was some segregation, was interesting, because in the early stages the cracking was wholly confined to a central band. Figure 4 shows the appearance of the cracks in this steel after a test in steam (*see* p. 144). The central region is practically δ-free. Cold work was found to cause considerably more transformation within this region than elsewhere.

Chemical analysis on a very small sample of drillings taken as far as possible from the cracked zone indicated that this zone contained less chromium than did the remainder, probably by about 1–2%.

EFFECT OF SOLUTION COMPOSITION

The effect of concentration and composition of the solution was investigated, and the results (Table III) show that many chlorides besides $MgCl_2$ can cause stress corrosion. Neutral chlorides such as NaCl and KCl are dangerous, but concentrated zinc, calcium, and magnesium chlorides seem to be even more so, either because of their much higher boiling points or because of slight acidity. In the latter solutions, cracks, once started, advanced rapidly, leading to actual failure (Fig. 5*a*); but in the solutions with lower boiling points the cracks generally advanced slowly, forming 'fans' (Fig. 5*b*). The 'fans' were found to grow very slowly, and in some instances specimens had not failed completely hundreds of hours after the cracks had first become obvious. In such cases, therefore, the time at which cracks became visible to the naked eye was recorded, instead of the time to failure.

The effect of the concentration of the plain sodium and magnesium chloride solutions is shown in Figs. 13 and 14; it appears that cracking can occur in solutions very much less concentrated than those commonly used for testing.

Tests were also carried out in chloride solutions to which certain additions had been made. The more interesting results are shown in Tables IV and V, from which it is obvious that oxidizing agents can greatly accelerate stress corrosion. The addition of dichromate to 3% NaCl is particularly spectacular, and it is likely that other oxidizing agents in certain critical concentrations may have similar effects. The additions of dichromate did not appear to be effective in the concentrated $MgCl_2$ solution, but $FeCl_3$ additions resulted in a considerable acceleration.

A few experiments with sulphates, bromides, and nitric acid solutions have not given failures, but cold dilute HCl and acid ferric chloride have been found to cause very slow cracking of 18/8 steels. Stronger hydrochloric acid has sometimes been used as a testing solution.[11]

Effect of Heat-Treatment

Low-carbon 18/10 specimens were bent in the usual U loops and were then annealed at various temperatures for 1 hr. After descaling, the specimens were loaded in the holders and were then tested in the $MgCl_2$ solution. Examination of the cracks showed that there was very slight branching on the specimens annealed at 700° C., and there was even less in specimens treated at 850° C. The cracking in the specimens annealed at lower temperatures was highly branched.

The temperature at which the internal stresses are relieved sufficiently to prevent stress corrosion in the

Table IV

EFFECT OF ADDITIONS TO 20 wt.-% NaCl SOLUTION ON THE STRESS CORROSION OF 18/8 STEEL IN A 4-DAY TEST

Addition	Observation
None	Fans as in Fig. 5*b*
1% $FeCl_3.6H_2O$	Acceleration, specimen almost broken*
5% $FeCl_3.6H_2O$	Great acceleration. Broken after 88 hr.
1% $CuSO_4.5H_2O$	No obvious acceleration
1% $Cr_2(SO_4)_3.18H_2O$	No obvious acceleration
5% Na_2SO_4	Not cracked (inhibition ?)
5% Sodium acetate	No acceleration
5% $NaCO_3$	Not cracked (inhibition ?)
5% $Na_2HPO_4.12H_2O$	No acceleration
1% K_2CrO_4	Slight acceleration
1% $Na_2Cr_2O_7(2H_2O)$	No acceleration
1% $NaNO_2$	Great acceleration
1% $NaNO_3$	Acceleration, many large fans

* Specimens compared with that in Fig. 5*b*

Table V

EFFECT OF ADDITIONS TO BOILING 3% NaCl SOLUTIONS ON THE STRESS CORROSION OF LOW-CARBON 18/10 STEEL*

Addition	Time to Cracking
1·5% $Na_2Cr_2O_7.2H_2O$	27–45 hr.
0·15% $Na_2Cr_2O_7.2H_2O$	27–45 hr.
1·5% $Na_2Cr_2O_7.2H_2O$ + 0·005% HCl	102–117 hr.
0·005% HCl	N.F.† in 388 hr.
0·125% K_2CrO_4	N.F. in 500 hr.

* No failures were obtained in plain 3% NaCl in 840 hr., and from Fig. 13 first signs of cracking are to be expected after about 2000 hr.
† N.F. = Not failed

absence of applied stresses has been investigated on titanium-stabilized 18/8 specimens, prepared by pressing Erichsen cups to within 10% of the breaking value. These were annealed and descaled and were then tested in the $MgCl_2$ solution in which, without annealing, cracking normally occurs in 2–3 hr. After boiling for 70 hr. it was found that the specimen which had been annealed for 4 hr. at 700° C. was badly cracked, but only one small crack was noticed in the specimen annealed for 18 hr. at 700° C.; a period of 15 min. at 800° C. was sufficient to prevent cracking.

EXPERIMENTS IN STEAM

Specimens, 6 in. × 1 in., made from the steels given in Table I and also from various titanium- and niobium-stabilized steels, were bent round a 1-in. dia. rod into **U** loops and were then bolted on a ¾-in. square mild-steel bar, the bend being downwards. The bar was placed in the steam space of a boiler operating at about 190° C. and 175 lb./sq. in., and was examined after 1300 hr. Many of the steels were found to have small cracks, some of which were visible only under a high-power microscope. Owing to the smallness of the cracks it is difficult to arrange the steels in their order of merit. It is interesting, however, that cracks were found even in the 18/18 Mo–Cu steel, which is a highly corrosion-resistant alloy and is relatively resistant to stress corrosion in the magnesium chloride test (*cf.* Table I). No cracks were noticed in the ferritic or martensitic steels tested at the same time.

The boiler was fed with normal town water, which had the approximate composition shown in Table VI. This water was treated with lime; the composition of the water left in the boiler at the end of a run, after cooling to room temperature, is also given in the Table.

MICROSCOPIC EXAMINATION

Stress-corrosion cracks are often very fine, being visible as lines at magnifications of 1000 diameters. The cracks are generally highly branched, and turn and twist across the grains so that they do not seem to follow any obvious crystallographic plane. Usually there is very little 'yawning,' even with very deep cracks.

Examination of strained austenitic steels, preferably after electropolishing and etching, shows that these steels are seldom single-phase. Neglecting the δ phase, which may sometimes be present, the steels also contain a martensitic phase, which is formed during straining of metastable austenite. This phase will be referred to as quasi-martensite (or 'pseudo-martensite').

Figure 6 is an etched view of quasi-martensite on a low-carbon 18/8 steel sample which transformed easily on straining; it is obvious that quasi-martensite tends to be formed on crystallographic planes, probably of high index. Figure 7 shows a specimen on which micro-hardness measurements were being taken on quasi-martensite. It is of interest that the two top right-hand impressions were made on what had been γ phase; the 'wings' of quasi-martensite resulting from these impressions are clearly visible in this unetched view. The other two impressions on the right-hand side may also have produced quasi-martensite, but not in a suitable orientation to be visible. The specimen was then corroded for 8 hr. in $MgCl_2$ solution, and the resulting etching (*see* Fig. 8) would seem to indicate that quasi-martensite is preferentially attacked by the solution.

Examination of cracks on surfaces polished before testing shows that a number of quasi-martensite particles have been severely attacked, and the main crack has frequent changes of direction connected with the plates of this constituent (Fig. 9). The relationship between quasi-martensite and cracking direction can be seen more clearly in a sample of 8/4/8 Mn–Cr–Ni large-grain steel (Fig. 10). In effect, it seems that cracking follows, wherever possible, the direction of quasi-martensitic plates but that the main direction of the crack is controlled by outside forces, so that in each grain more than one plane is involved.

In steels containing δ phase the cracks avoid this constituent wherever possible (*see* Fig. 11 for an 18/8 molybdenum steel). As far as it is possible to judge, the same thing happens with smaller particles of the δ constituent, but the effect is not easy to demonstrate.

In steels such as 25/20, 12/12, and the relatively stable austenitic steels given in Table II, the cracking is generally less branched than in the 18/8 steels, and there are fewer changes in direction within each grain (Fig. 12). On the other hand, in steels *C* and *D*, which transform easily, the cracks are usually wider, and many of them could be regarded as elongated pits. Most of the failures in steel *D* occurred away from the **U** bend, *i.e.*, at places where relatively little transformation had taken place.

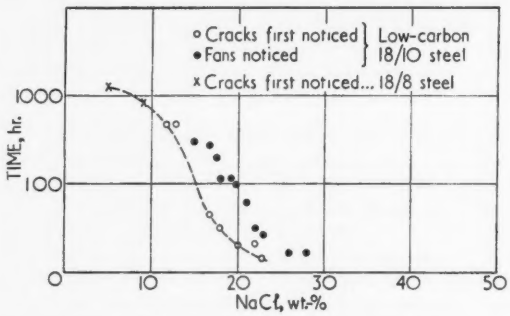

Fig. 13—Effect of NaCl concentration on stress corrosion

DISCUSSION OF RESULTS

Highly localized corrosion with the formation of narrow cracks can take place only if the corrosion products are very soluble in the solution inside the crack. Since failures occur even in neutral and reasonably dilute solutions in which chromium oxide (or hydroxide) is hardly soluble, it seems likely that the solutions inside the crack have a much lower *p*H value than the bulk of the solution. A mechanism that could lead to a local fall in *p*H during the corrosion of aluminium alloys has been proposed,[18] and qualitatively it seems applicable to steel[19] and to the present alloys. If this mechanism is correct, the anodic reaction is autocatalytic (*i.e.*, it takes place more readily at high rates than at low rates) and therefore tends to become concentrated on very small areas. In single-phase alloys the attack should lead to pitting, which would not cause undue mechanical weakening, as is found to be the case. However, if plates of a second phase, which is preferentially attacked, are present, the corrosion would be concentrated on these and would form trenches and eventually cracks, more because of continuous attack on these plates than because of an actual increase in corrosion rate. If a great deal of second phase is present, the corrosion will not be concentrated on any particular plate and will be less likely to lead to rapid penetration. This would explain why the two alloys *C* and *D*, which contain large quantities of quasi-martensite, do not crack easily, and it would also explain the wide irregular crack shown in Fig. 12c. In more stable austenitic steels it seems probable that there is not a continuous network of quasi-martensite, and that the crack often cannot proceed until the steel yields and produces more quasi-martensite. Such yielding could result either from the corrosion of some adjacent plate of quasi-martensite, or from weakening due to ordinary corrosion of austenite. The scatter of the results with the more resistant steels can be attributed to the absence of a regular network of quasi-martensite in these steels.

The fact that quasi-martensite results from local stresses set up during cracking is shown by Fig. 10, for an 8/4/8 Mn–Cr–Ni steel; this sample was loaded by direct tension to only 30 tons/sq. in., which in this steel is known to produce very small quantities of quasi-martensite.

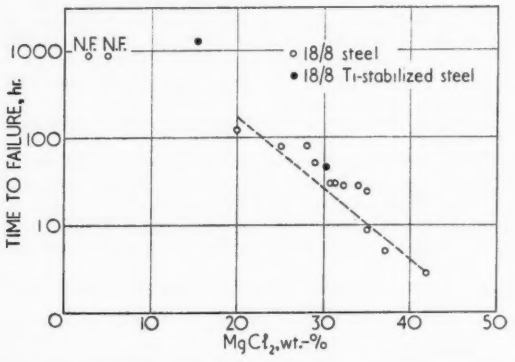

Fig. 14—Effect of $MgCl_2$ concentration on time to failure

Table VI
WATER COMPOSITION

	Feed Water, p.p.m.	At End of Run, p.p.m.
Total Solids	85	3020
Chlorides	12·6	780
Sulphates	28·4	n.d.*
Carbonate	6·6	n.d.
Calcium	11·0	180
Magnesium	3·4	2·2
Sodium	8·5	720

* n.d. = Not determined

There seems little doubt that this particular type of stress corrosion is connected with the attack on quasi-martensite, but it is not clear why this phase, which almost certainly has the same composition as austenite, is preferentially attacked. It is probable that the quasi-martensite is under very high stresses, and there is considerable evidence that stress can increase corrosion rates of steel[20, 21]; but this may not be the whole explanation, since stress corrosion is slow in steels in which the transformation does not readily occur and in which the austenite at the tip of the crack must also be highly stressed. It is worth considering the possibility that tempering of quasi-martensite in the boiling solution during the experiment may cause rupturing of the protective film covering it and thus make the quasi-martensite more prone to attack. Since no appreciable tempering of the relatively low-carbon martensite could occur at room temperatures, this may explain why no reagent has yet been found which causes rapid transgranular stress corrosion at low temperatures. In this connection, it is interesting that the higher carbon (approximately 0·6% C) austenitic steels containing 4–8% Cr and with high manganese and nickel contents have been found to be susceptible to stress corrosion even at room temperatures. The comparison between the two types of steel may not, however, be justified, because of the great differences in corrosion properties between them.

It is often assumed that rapid cracking is possible only if the corrosion is also rapid, and although this may be true it seems unlikely that corrosion on its own causes appreciable penetration. For instance, some of the cracks have been found to penetrate at rates greater than 1 cm./hr., and it is difficult to imagine that corrosion could occur at such rates and that the necessary electrolytic currents could flow out of the cracks. It seems much more likely that the corrosion in some way continuously triggers off a deformation process, which in turn causes the cracking. One possible explanation is suggested by the work of Menter and Hall,[22] who believe that oxide films can hinder the movement of dislocation, and it may be that the main rôle of corrosion is to maintain a given place at the tip of the crack relatively film-free.

This view is not incompatible with the idea that the film on quasi-martensite ruptures from time to time because of tempering, since in the absence of suitable corrosive conditions oxide would rapidly re-form.

The effect of steel composition on the stability of austenite has been studied by numerous workers, and

a useful semi-quantitative guide is given by Schaeffler.[23] Nickel, manganese, and carbon are austenite stabilizers in the full sense of the word, whilst chromium and molybdenum, although tending to close the γ loop, also inhibit the martensitic transformation and therefore act as austenite stabilizers at low temperatures. If, however, too much chromium is added, a two-phase alloy is formed, and from the phase diagram it would appear reasonable to expect the austenitic phase in the duplex alloy to be nickel- and carbon-rich and the ferritic phase to be chromium- and iron-rich. It appears, therefore, that the addition of more than 18% of Cr to an 8% Ni steel indirectly causes an increase in the nickel content of the austenite without perhaps causing a large increase in its chromium content. Such austenite would be expected to be rather more stable at low temperatures than the 18/8 composition. The addition of small quantities of titanium and niobium causes a decrease in the effective concentration of carbon, and this probably explains why, in the titanium-stabilized steels, the minimum resistance to stress corrosion under the present conditions of testing seems to be at a somewhat higher nickel level than in the plain chromium–nickel steels. The results obtained with the steel containing manganese, copper, and nitrogen additions were disappointing, since these elements are generally regarded as austenite stabilizers.

The difference between the types of failure shown in Figs. 5*a* and *b* is thought to be due to the difference in the rate of cracking. In the first case this rate is rapid, and it seems reasonable to expect that when a crack advances far ahead of others it cracks the specimen without greatly affecting its neighbours; but in the second case the cracks advance slowly, and the fan is formed because of the stress-relieving effect of each crack on the region near it. This may explain why the first type of cracking is more liable to occur in the high-boiling-point solutions.

The accelerating effect, on the cracking, of some of the oxidizing agents is probably due to their depolarizing effect on the cathodic reaction, which in the boiling solutions must be starved of oxygen.

Most of the present work confirms the earlier work of Rocha and Tofaute,[12] who have also shown that cold working can either have a beneficial effect or cause more rapid failure, depending on circumstances. This is to be expected if, as suggested in the present paper, the maximum susceptibility to stress corrosion depends on the formation of a critical quantity of quasi-martensite; but the quantitative interpretation of the results is difficult because, in addition to the susceptibility to stress corrosion, the mechanical properties of the steels alter with both cold work and chemical composition.

CONCLUSIONS

The present work supports the contention that the transgranular stress corrosion of austenitic chromium–nickel steels is due to preferential attack on small quantities of quasi-martensite, which form in this type of steel on straining. The susceptibility can be reduced either by increasing the nickel content of the normal 18/8 steels and thus increasing the stability of the austenite, or by reducing the alloy content and thus producing a steel which contains large quantities of quasi-martensite and in which corrosion is more widely distributed. Increasing the chromium content also leads to some improvement, presumably because the austenite in the two-phase alloys produced in this manner is relatively stable at low temperatures.

Transgranular stress corrosion can occur in many solutions containing chlorides, and oxidizing agents can accelerate failures. Impure steam may also cause stress corrosion.

Annealing treatments above 850° C. should remove internal stresses below a value at which the danger from stress corrosion is great.

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Line-Broadening of Martensite in Nickel Steels

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SYNOPSIS

The X-ray diffraction-line shapes obtained from quenched medium- and low-carbon nickel steels have been recorded in a Geiger counter spectrometer. Fourier analysis has been used to determine the true physical broadening from the observed line shapes of the martensite and of annealed iron which is assumed to exhibit experimental broadening only. Further information on the nature of the transformed material is obtained from a consideration of the Fourier coefficients themselves.

The results indicate that the effects produced by martensitic transformation are similar to those obtained in cold-worked metals. Earlier work is substantiated in that the major part of the line-broadening is due to internal stresses, but the results indicate the presence of a particle-size effect. The carbon content is effective in determining the degree of internal strain remaining after transformation. 718

THE broadening of X-ray diffraction-line profiles is, in general, attributed to two types of lattice imperfection. These are: (1) Differences in parameter due to the presence of residual internal strains, and (2) a small particle-size effect, which implies the formation of some form of substructure within the original grains. The broadening expected from these two types of imperfection has been calculated. Thus, for a reflection at a Bragg angle θ, the broadening produced by lattice strain is given by:

$$\beta_s = \eta \tan\theta \quad \ldots\ldots(1)$$

where η is the effective strain perpendicular to the reflecting planes. A substructure with an average particle size ε produces a broadening β_p, given by:

$$\beta_p = \lambda/\varepsilon\cos\theta \quad \ldots\ldots(2)$$

where λ is the wavelength of the radiation used. If the material concerned is mechanically isotropic and the substructure has spherical particles, equations (1) and (2) may be rewritten:

$$\beta_s\cot\theta = \text{constant} \quad \ldots\ldots(1a)$$
$$\beta_p\cos\theta = \text{constant} \quad \ldots\ldots(2a)$$

Dehlinger and Kochendörfer[1] pointed out that if both particle-size and stress effects were causing line-broadening, the former would be most appreciable at low diffraction angles. Since metals rarely diffract at very low angles, the tendency would be to overlook the particle-size effect. Assuming, as a first approximation, that the broadening due to the two effects is additive, equation (3) is obtained:[2, 3, 4]

$$\beta\cos\theta/\lambda = \sin\theta/\lambda + 1/\epsilon \quad \ldots\ldots(3)$$

Mazur interpreted the line breadths of quenched eutectoid and hypereutectoid steels on the basis of this relationship. He estimated the particle size to be about 30 interatomic distances or 7×10^{-7} cm. A substructure on this scale would account for an appreciable part of the line-broadening and is at variance with the results obtained by Wheeler and Jaswon[5] for quenched hypereutectoid steel.

EXPERIMENTAL

In the present work a departure has been made from previous investigations in that medium- and low-carbon nickel steels have been used instead of plain carbon steels. This has definite advantages since, firstly, the martensite has a body-centred cubic crystal structure and, secondly, the small amount of retained austenite in low-nickel alloys quenched to room temperature has a negligible effect on the line shapes. Both these properties lead to a much less complicated diffraction pattern than is obtained from plain carbon steels, and it is not necessary to use the complicated technique utilized in the earlier work to resolve the individual martensite lines.

The diffracted intensity was recorded directly, using a Geiger counter, thus eliminating the difficulties of maintaining constancy of processing and densitometry. The apparatus has been described elsewhere.[6] Solid disc specimens, 1 in. dia. and about $\frac{1}{16}$ in. thick, were prepared from three different alloys. Specimens *FN*1 and *FN*2 were obtained from hot-rolled bars of commercial 3% Ni steels, the specifications, according to the makers, being as follows:

	*FN*1	*FN*2
Ni, %	2·75–3·25	2·75–3·25
Cr, %	0·6 –0·8	...
C, %	0·28–0·35	0·10–0·15
Mn, %	0·6 –0·8	0·2 –0·6
P, %	0·04	0·04
S, %	0·04	0·04
Si, %	0·3	0·25

Specimen *FN*3 was obtained from an ingot made from pure materials, melted together in an alumina crucible in a high-frequency furnace. The currents set up in the molten metal ensure adequate mixing of the constituents and, although the melt was allowed to solidify in the furnace, the freezing range is so narrow that no great inhomogeneity should be produced in the small specimens used. The materials used were as follows:

Paper MG/A/39/52 of the Alloy Steels Committee of the Metallurgy (General) Division of the British Iron and Steel Research Association, first received 11th March, 1952, and in its final form on 4th November, 1952. The views expressed are the author's and are not necessarily endorsed by the Committee as a body.

Dr. Smith, formerly at the Department of Metallurgy, Birmingham University, is now in the Development and Research Department, The Mond Nickel Co., Ltd.

Nickel Powder—Spectrographic analysis showed that only magnesium gave strong lines
Iron—The main impurities were 0·025% C, 0·034% Mn, 0·015% S, 0·010% P, and 0·001% Si.

The analyses of the actual X-ray specimens are listed in Table I, together with the conditions in which the specimens were examined.

The disc specimens were clamped, two at a time, between copper plates and were heated to the austenitizing temperature by immersing the assembly in a salt bath maintained at 910–920° C. After soaking for 5–10 min., the assembly was quenched in cold water, the copper plates preventing buckling of the thin specimens. The plates also protected the specimens from attack by the atmosphere and the salt. One specimen (*FN1B*) was subsequently tempered by immersing it for 20 hr. in a salt bath maintained at 475° C. Specimen *FN1C* was decarburized by holding it for 20 hr. at 725° C. in an atmosphere of wet hydrogen. This specimen was then subjected to the quenching treatment already described.

After treatment, each specimen was mounted in the spectrometer. During experiments the specimens were rotated at about 20 r.p.m. in a beam of crystal-reflected, cobalt Kα radiation. The diffracted intensity was recorded by a Geiger counter operating at 1550 V. Measurements were carried out at angular intervals ranging from 30 min. of arc over the background remote from the peaks, to 2 min. of arc over the peaks themselves. Counts of 1 min. were made using a timing unit, designed and constructed by Dr. U. W. Arndt, which stopped the scaling unit after the exact time interval required. The observed counting rates were corrected for counting losses caused by the dead times of the counter and its associated circuits, allowance being made for the pulsed output of the X-ray tube. The incident intensity of the X-ray beam was hand-controlled by a 'Variac,' which regulated the voltage supplied to the filament. Checks made on the peak of the strongest (110) reflection before and after the recording of each line showed that the incident intensity could be maintained constant to within ± 2%.

After the recording of each martensite spectrum, measurements were made of the line shapes of an Armco iron specimen which had been annealed for 2 hr. at 650° C.

Table I

ANALYSES OF SPECIMENS SUBMITTED TO VARIOUS TREATMENTS

Specimen	Condition of Specimen	Nickel, wt.-%	Carbon, wt.-%
FN1A	As quenched from 910° C.	3·12	0·29
FN1B	As *FN1A* + 20 hr. at 576° C.	...	...
FN1C	Decarburized and quenched from 910° C.	3·19	0·1
FN2A	As quenched from 910° C.	2·75	0·17
FN3A	As quenched from 920° C.	9·80	<0·05

FOURIER ANALYSIS OF LINE SHAPES

The method of analysis used in the present work was based on that of Stokes[7] and of Stokes and Wilson.[8] A brief outline is given here so that the experimental results may be understood.

The breadths of the iron lines are assumed to be determined solely by the experimental conditions, whilst the broader lines of the martensite spectrum involve this factor and also the so-called physical broadening.

The distribution of intensity $h(x)$ in a broadened, martensite line is represented by the Fourier series:

$$h(x) = \Sigma C_N \cos Nx.\delta x \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Theoretically, the expansion should also contain sine terms, but these vanish if the function is symmetrical about its peak. Actually, the measured line shapes were not generally symmetrical, due to inhomogeneity of the incident radiation, vertical divergence of the beam, etc. It seems reasonable, however, to assume that the broadening function itself is symmetrical, and thus that the sine terms would eventually vanish.

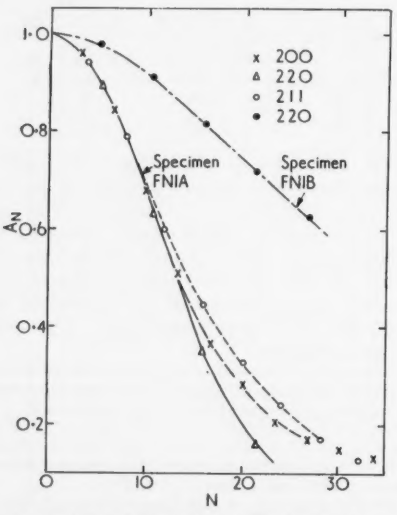

Fig. 1—Variation of Fourier coefficients A_N with N (values of A_N obtained from analysis of line shapes)

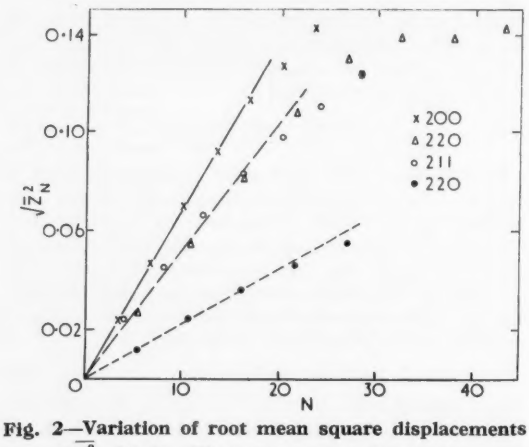

Fig. 2—Variation of root mean square displacements $\sqrt{Z_N^2}$ with N. The lower curve refers to specimen *FN1B*

The sine terms have therefore been neglected and only the low-angle portion of the lines, to which the α_2 component of the radiation makes but a small contribution, has been considered.

A complete analysis of the broadening of lines obtained from a cold-worked aluminium specimen, using both sine and cosine terms, was carried out by Dr. W. H. Hall and Dr. G. K. Williamson. Their results showed the sine terms to be negligible, and a cross check against these results indicated that the shortened procedure used in the present work was satisfactory.

The Fourier coefficients C_N are evaluated from the measured intensity distribution as

$$C_N = h(x)\cos Nx.\delta x \quad \ldots\ldots(5)$$

The interval δx is maintained constant throughout and can therefore be omitted. A series of coefficients C_N for $N = 0, 1, 2$, etc., is thus obtained. Similar coefficients B_N are obtained for the corresponding iron line and it can be shown[7] that the coefficients A_N of the broadening function are given by:

$$A_N = C_N/B_N \quad \ldots\ldots(6)$$

The ordinates of the broadening function are then obtained from the relation expressed in equation (4). The Laue breadths of the broadening functions are easily obtained and, in so far as the assumption made above is justified, these give the true physical broadening.

The recent work of Warren and Averbach[9] and of Hall[10] has shown that by a suitable choice of the range in x over which the summations are carried out, more detailed information regarding the internal structure of the martensitic material can be obtained from the Fourier analysis. The order N of the harmonic refers to a distance, in the crystal giving rise to the reflection, which is a multiple (N times) of a certain unit length. This unit length can be made equal to the interatomic distance by the correct choice of integration range. If the coefficients A_N are plotted against N, curves of the form shown in Fig. 1 are obtained. The tangent to these curves at $N = 0$ gives an intercept, on the N-axis, equal to the average particle size in the direction perpendicular to the reflecting planes concerned.

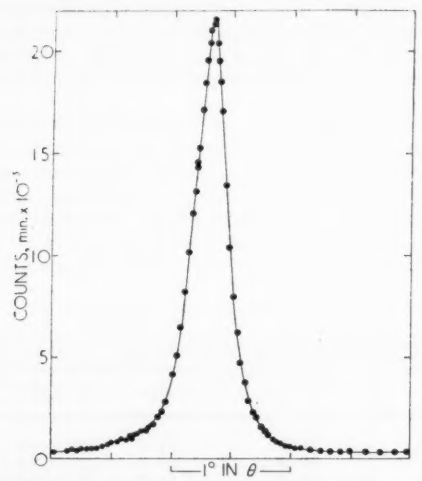

Fig. 3—Recorded shape of the 110 martensite reflection from a specimen of 3% nickel steel

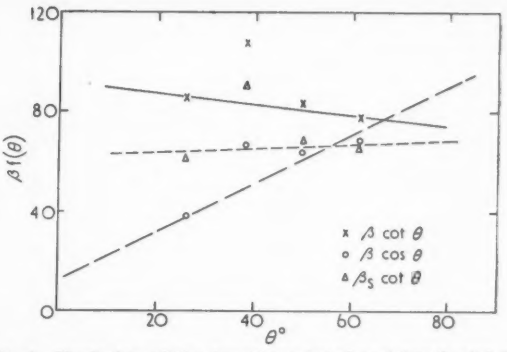

Fig. 4—Variation of the functions $\beta\cos\theta$ and $\beta\cot\theta$ with θ

Information can also be obtained regarding the atomic displacement caused by residual internal stresses. Assuming that the displacements follow a Gaussian distribution law,

$$A_N = \exp.(-2\pi^2h^2\overline{Z_N^2}) \quad \ldots\ldots(7)$$

where $\overline{Z_N^2}$ is the mean square displacement and h is the order of the reflection. If the root mean square displacement is plotted against N, curves of the form shown in Fig. 2 are obtained. Initially, these graphs are linear since, for constant strain e:

$$\sqrt{\overline{Z_N^2}} = eN \quad \ldots\ldots(8)$$

The value of N corresponding to the departure of these curves from linearity gives an indication of the distance over which the internal stresses, averaged statistically over all the grains, are constant. The slopes of the initial portions of the curves give the average strain in a direction perpendicular to the planes concerned.

Details of the procedure adopted to obtain the Fourier coefficients from the measured line profiles and the subsequent evaluation of the ordinates of the broadening function are dealt with by Stokes.[7]

EXPERIMENTAL RESULTS

The observed counting rates, suitably corrected for counting losses, were plotted against the angle of arc χ, measured round the spectrometer. The spectrum so obtained for specimen *FN1A* showed two main points of difference from that of annealed iron. These were the appreciably higher background and the much broader line profiles of the martensite spectrum. The ordinates used in the Fourier analysis were read from smooth curves drawn through the plotted experimental points. The greater simplicity of the spectrum obtained with nickel steel specimens, compared with that of plain carbon steel, is illustrated in Fig. 3, which shows the 110 martensite reflection in the spectrum of specimen *FN1A*. There is no indication of the presence of a doublet or of an overlapping austenite line. Measurement of the 200 austenite reflection showed that the amount of retained austenite was negligibly small, and the 111 reflection would have little effect on the shape of the 110 martensite line.

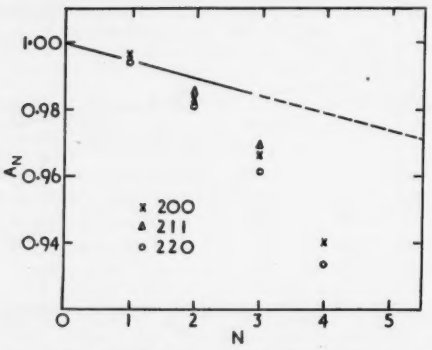

Fig. 5—Variation of Fourier coefficients A_N with N (values A_N obtained by the interpolation method)

Using the measured ordinates, the broadening function was determined for each reflection, and the Laue breadths of these functions were determined. Figure 4 shows the variations of the functions $\beta\cos\theta$ and $\beta\cot\theta$ with θ, from which it appears that lattice distortions are the main cause of line-broadening. The 200 reflection shows an exceptionally high broadening.

Treatment of the Fourier coefficients as described indicates the existence of a substructure on a scale small enough to cause appreciable line-broadening. The variation of the coefficients A_N with increasing order of the harmonic is shown in Fig. 1. The initial slopes of the curves, although much the same for all reflections, are not very closely defined owing to the high value of N at which the first analytical results occur.* Approximate values of A_N at smaller values of N were obtained utilizing equation (7). The magnitudes of the root mean square displacements were obtained and these are plotted as a function of N in Fig. 2. The initial parts of these graphs are linear and it is possible to interpolate and obtain reasonably accurate values of $\sqrt{\overline{Z_N^2}}$ for $N = 1, 2, 3$, etc. Corresponding values of A_N are easily obtained and these are plotted against N in Fig. 5. The initial slope of the curves has been taken as the straight line drawn through the values of A_N for $N = 0$ and $N = 1$. Extrapolating this line to cut the N-axis, a minimum value is obtained for the average particle size in terms of the interatomic distance. This was $192a$ or $5{\cdot}5 \times 10^{-6}$ cm., assuming a value of $a = 2{\cdot}86$ Å. The broadening expected from a substructure on this scale may be calculated from equation (2). Assuming that the total broadening is the summation of that due to small particle-size effects and that due to lattice distortion, the breadths β_s should obey equation (1a). Table II shows that this is true to within $\pm 6\%$, with the exception of the 200 reflection which gives a high value. The values of $\beta_s\cot\theta$ are also included in Fig. 4.

The observed breadths are plotted against $\sin\theta$ in Fig. 6. Including, at $\sin\theta = 0$, a value of 11·2, corresponding to the particle size estimated from the Fourier coefficients, a reasonably straight line can be drawn through the experimental points. The slope of the line, $\beta\cot\theta$, is proportional to the effective internal strain. The average root mean square strain ($\frac{1}{4}\beta\cot\theta$) for the directions [110] and [211] is thus about 0·47%. This may be compared with the value of about 0·5% given by the slope of the curves for the corresponding reflections in Fig. 2. The average internal stress in the material may be estimated as:

$$\delta = \tfrac{1}{4}E\beta\cot\theta = 66 \text{ tons/sq. in.}$$

One other point of interest arises in connection with the relationships expressed in equation (8) and shown graphically in Fig. 2. The results show that the values of $\sqrt{\overline{Z_N^2}}$ are proportional to N up to values of about 20. This indicates that the internal stresses in martensite are extremely short range in nature.

The analysis of the spectrum of specimen *FN1A* was carried out to completion, and the results have been described in detail; but results of the same general nature were obtained from the analyses of all the spectra investigated. The line profiles of specimen *FN1B*, which had been subjected to a tempering treatment, although much sharper than those of specimen *FN1A*, still exhibited physical broadening. The background level of this specimen was again appreciably higher than that of the annealed iron specimen. The analytical results, illustrated in Figs. 1 and 2, showed that the average internal strain was reduced by tempering and the substructure became coarser. Both these effects lead to a reduction of broadening.

The effect of carbon was illustrated by the greatly reduced broadening exhibited by specimen *FN2A* compared with *FN1A*. Both specimens had approximately the same nickel content and had been similarly heat-treated. Specimen *FN3A* contained 9% of nickel, but had less than 0·05% of carbon, and this also exhibited less broadening than specimen *FN1A*

* As already mentioned, if the correct range of integration is used, the coefficients A_N are related to distances in the crystal that are multiples of the interatomic distance. In Stokes' method of analysis, the range of integration is chosen arbitrarily, solely for convenience of analysis. The resulting coefficients A_N are therefore related to arbitrary distances $N_1\alpha_1$ in the crystal. They are then converted into terms of the interatomic distance α, where $N_1\alpha_1 = N\alpha$. The experimental results therefore occur at values of $N = P, 2P, 3P$, etc., where $P = \alpha_1/\alpha$.

Table II

BROADENING OF DIFFRACTION LINES DUE TO SMALL PARTICLE SIZE AND LATTICE DISTORTION

Line Indices	β_L, min.	β_p, min.	β_s, min.	$\beta_s\cot\theta$, min.	$10^{-6}E$, lb./sq. in.	$\frac{1}{4}E\beta\cot\theta$, tons/sq. in.
110	42·6	12·4	30·2	61·3	31·3	62·3
200	85·7	14·3	71·4	89·3	18·9	54·8
211	98·6	17·3	81·3	68·4	31·3	69·3
220	145·2	23·7	121·5	64·8	31·3	65·8

after the same treatment. The reduced broadening exhibited by specimen *FN1C*, compared with specimen *FN1A*, was direct evidence for the effect of carbon since the measurements were carried out on the same specimen but before and after a decarburizing treatment. No analysis was made of the spectrum of specimen *FN1C*. The results of analyses of the other spectra are collected in Table III, which gives estimated values for the particle size and the average internal stress. The results may be compared with Vickers hardness numbers determined from indentations made on the X-ray specimens themselves.

Owing to the limitation of the range of integration in the Fourier analysis of line shapes by Stokes' method, the numerical results in Table III are only an indication of the trends of stress and particle size.[11]

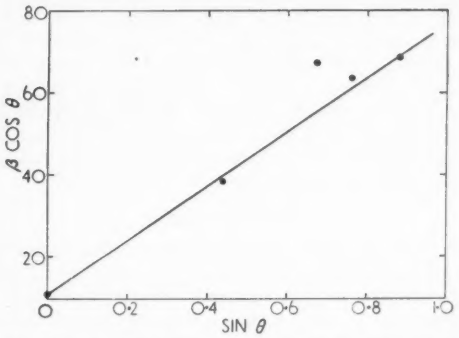

Fig. 6—Variation of $\beta\cos\theta$ with $\sin\theta$ for specimen *FN1A*

DISCUSSION

The line-breadth measurements on the quenched alloy *FN1A* indicate that the major part of the line-broadening is due to internal stresses. This agrees with the results for plain carbon steels obtained by Wheeler and Jaswon[5] and by Krainer.[12] The variation of $\beta\cos\theta$ with $\sin\theta$ (Fig. 6) suggests, however, that a substructure effect also contributes to the observed line shapes. An approximate minimum value for the particle size of $5{\cdot}5 \times 10^{-6}$ cm. is obtained from a consideration of the Fourier coefficients. Assuming that the total broadening is approximately the summation of the components due to distortion and small particle size, it is possible to estimate the broadening due to the former effect. Excluding the 200 reflection, the values of this component are proportional to $\tan\theta$, within 6%. This result would be expected from equation (1) and it supports the analytical procedure adopted. Further justification of the method is found in the agreement between the values of the average internal strain as determined from the line breadths (Fig. 6) and from the Fourier coefficients (Fig. 2).

Table III indicates that the internal stress increases rapidly with increasing carbon content, and this agrees with the fact that other workers,[5, 12] using hypereutectoid steels, reported larger values than were observed in the present experiments. The rapidly varying nature of the internal stresses, as demonstrated by the early divergence from linearity of the curves of Fig. 2, suggests, however, that little significance beyond a general indication of the magnitude of the distortion should be attached to the values for the average stress.

The relatively high breadths observed for the 200 reflection are most probably associated with lattice-distortion effects rather than with a variation of particle size with crystallographic direction, since the initial slopes of the curves of Fig. 1 are appreciably the same for all reflections. Previous workers have attributed this result to the markedly lower value of Young's modulus for iron in the [100] direction, compared with the other directions concerned. As in earlier work,[5] the present results lead to a relatively low value of $E\beta_s\cot\theta$ for this reflection on the assumption of a uniform distribution of internal stress, although, as shown in Table II, this is more nearly justified than the assumption of a uniform distribution of strain.

It is appropriate at this point to refer to an anomaly which arose in the Fourier analysis results. This occurred in the evaluation of the root mean square displacements from the coefficients. The calculated values indicated a larger strain in the [110] direction than in the [220] direction, a physically unreal result. This discrepancy is unexplained but may be due to the assumption of a Gaussian distribution of displacements.

Comparison of the results from specimens *FN1A* and *FN1B* showed that, on tempering, the average internal stress decreases and the average particle size increases. This agrees with recent work of Krainer, who analysed the line-broadening in a series of tempered steel specimens and showed that the internal strain decreased and the particle size increased as the tempering temperature was raised.

The estimated values of the average internal stress in specimens *FN1* and *FN2* were much smaller than the values of the elastic limit obtained from tensile tests. This observation is at variance with the results

Table III

SUMMARY OF EXPERIMENTAL RESULTS FOR THE SPECIMENS INVESTIGATED

Note—The U.T.S. values are assessed from the hardness measurements and give only a general indication of the relationships

Specimen	Internal Stress, tons/sq. in.	Particle Size, cm.	V.P.H.	Ultimate Tensile Strength tons/sq. in.
FN1A	66	$5{\cdot}5 \times 10^{-6}$	599	117
FN1B	31	$3{\cdot}8 \times 10^{-5}$	369	78
FN2A	28	$4{\cdot}2 \times 10^{-5}$	...	...
FN3A	30	$4{\cdot}0 \times 10^{-5}$	354	75

obtained previously for plain carbon steels, and for several cold-worked metals,[13] which indicated that the average internal stress was of the order of the ultimate tensile strength. Approximate values for the ultimate tensile strengths of the materials used in the present work may be assessed from the hardness measurements. These are about twice the values of the average internal stress.

CONCLUSIONS

(1) The similarity between the general appearance of the spectra of cold-worked and martensitic specimens has long been recognized. The marked similarity in details as shown by the present work (*e.g.*, the high background level and the short-range nature of the internal stresses, as well as the dual source of line-broadening) and by that of Hall and Williamson[14] on cold-worked metals, indicates that the structure of martensite differs from that of a cold-worked material only in degree, and the unusually large broadening is not a consequence of a separate phenomenon.

(2) The major part of the line-broadening may be attributed to distortion of the lattice during transformation, but the results indicate that a substructure, which can cause some broadening, is formed.

(3) The scale of the substructure decreases with carbon content in the range investigated and is increased by tempering. The particle size is estimated to be of the order of 10^{-5} to 10^{-6} cm.

(4) The internal stresses remain uniform only over short distances. The average internal stress, which is about half the value of the macroscopic ultimate tensile strength of the material, increases with carbon content and is decreased by tempering treatments.

Acknowledgments

The author thanks Professor D. Hanson, D.Sc., under whose general guidance the present work was carried out. He also acknowledges his indebtedness to his colleagues Dr. U. W. Arndt and Dr. W. H. Hall for their help and advice throughout this research, and to Professor A. H. Cottrell and Dr. M. A. Jaswon for many helpful discussions and suggestions. Finally, thanks are due to the British Iron and Steel Research Association for financial support and for permission to publish this paper.

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Letters to the Editor

INTERCRYSTALLINE CRACKING OF METALS

In a previous letter,[1] I drew attention to the possibility that the movement of vacant lattice sites under stress and their accumulation at grain boundaries might be a cause of intercrystalline cracking. At that time, I envisaged the vacant sites forming a uniform layer at the boundary, and thus causing a breakdown of cohesion. Tensile stress across the boundaries would then cause separation and ultimate cracking.

In working on the intercrystalline cracking of copper and brass, we have found that the cracking is preceded by cavitation at the grain boundaries. These cavities are considered to be the result of the accumulation of vacant lattice sites migrating under stress.

It would be interesting to know whether such intergranular cavitation has been noted in high-temperature alloys that have failed under creep conditions. A fuller statement of my views is contained in a recent letter to the Journal of the Institute of Metals.[2]

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1. J. N. Greenwood: *J. Iron Steel Inst.*, 1952, vol. 171, p. 380.
2. J. N. Greenwood: *J. Inst. Metals*, 1952, *Bull.*, vol. 1, No. 14, pp. 120–121.

I am glad to note from Mr. Frey's letter[1] that he is in agreement with the general idea that the migration of vacant lattice sites under stress can lead to intercrystalline cracking.

Up to the present I have been more interested in checking the possibility by further experiment than in thinking of possible mechanisms in terms of movement of dislocations.

There are two sources of vacant sites, *i.e.*, those in equilibrium with the lattice due to thermal movement of atoms, and those caused by geometrical consideration of crystal deformations. These two sources may be in opposition in the sense that as the temperature is raised, thereby increasing the thermal supply of vacant sites, geometrical deformation—*e.g.*, by slip—decreases. However, rate of strain is also a factor in this connection.

Mr. Frey's suggestion that a precipitate would delay cracking is one that would naturally follow if the postulate that vacant sites can become trapped at a lattice discontinuity is correct. The discontinuity at an interphase boundary would certainly be expected to be greater than that at a grain boundary.

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1. D. N. Frey: *J. Iron Steel Inst.*, 1953, vol. 173, p. 51.

THE KING'S IRONWORKS
IN THE FOREST OF DEAN, 1612–1674

BY DR. H. R. SCHUBERT

SYNOPSIS

Blast-furnaces and forges on Crown property in the Forest of Dean were first erected in 1612. They were destroyed in 1644 and, after a limited re-erection, were finally abandoned in 1674. In 1635, a detailed inventory of buildings and implements was made. This inventory, which is now published in its original form for the first time, and the ruins of one of the furnaces, situated at Parkend, render it possible to reconstruct the state of an English ironworks and the various processes employed in the 1630's. Production figures are also available. 736

In the course of the sixteenth century the victorious march of the blast-furnace extended almost all over England and Wales. It is surprising that the Forest of Dean remained unaffected by this development, since it had been one of the principal centres of iron production in the Middle Ages. The reason, however, was the need for preserving the fine store of oaks and beech trees of the Forest, to meet the growing demand for ship's timber for the merchant fleet and the Royal Navy. A blast-furnace with its tremendous consumption of charcoal made of wood was a potential danger in this respect, of which, in particular, the merchants and shipbuilders of Bristol were well aware. Consequently, the old primitive bloomeries which consumed much less charcoal were left undisturbed as the only iron producers in the Forest.

By 1600, however, the blast-furnace had reached the border of the Forest, both north and south. First evidence of a furnace at Lydbrook, on an eastern tributary of the River Wye and halfway between English Bicknor and Ruardean, is of the early 1590's when a test was made[1] of Osmond iron produced there from 'raw iron.' The furnace stood on the property of Robert Devereux, the second Earl of Essex; at the time of his attainder for high treason and execution in 1601, this property was forfeited to the Crown.

On the opposite side of the Forest and near the estuary of the River Severn, there was a furnace not much later. It stood near Lydney, on the property of Sir Edward Wynter. In 1604, he obtained a licence for cutting down trees on his estate to convert them into charcoal "*for the makeing and workeing of iron.*" Two years later his ironworks at Lydney was described as consisting of a furnace and a forge.[2]

The erection of blast-furnaces within the Royal demesne of the Forest of Dean was seriously taken into consideration in the years 1609 and 1610. In a letter of 26th April, 1609, George Moore, steward of Goodrich Castle, in Herefordshire, which belonged to Gilbert, Earl of Shrewsbury, informed his master of plans being made for the erection of new ironworks in the Forest of Dean. He added that there were "*divers good rivers and mine of iron-stone in all parts of the same and the woods so stately and such planted, as will continue 6 furnaces and as many forges at least 20 or 30 years.*"[3]

Such plans were very much in the air in those years. They were even connected with a project of erecting ironworks on English plantations in Ireland. In 1610, an ironmaster named Tokefield, who was a partner of an ironworks on the River Shannon and acted as an agent for Sir Arthur Chichester, Lord Deputy of Ireland, to discover suitable sites for ironworks, stated that the Irish ore was "*not as yeldable as the English iron ore.*" He therefore proposed that King James I, who had "*great stores of woodes*" in the Forest of Dean, should erect four furnaces in the Forest. The pig iron produced by them should be sent to Ireland *via* Bristol and worked there into bar iron.[4] Tokefield's project was readily accepted by Sir Arthur and also by Sir Richard Morison, Vice-President of the Irish Province of Munster. Both advised the Earl of Salisbury, the leading Secretary of State in England, to set up a "*furnace or two in the Forest of Dean, and a forge or two in Munster to worke the sow iron that shall come from thence into bars.*" Sir Arthur, however, did not conceal that Tokefield had been too optimistic in estimating the total expenses for erecting an ironworks with stock at £1000. His doubts were based upon a statement by Sir Richard Boyle, one of the greatest ironmasters in his day, who later became the first Earl of Cork. Boyle, a shrewd and

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[1] The test was made at a time when John Challoner had the lease of the Tintern wireworks, which he held from 1591 to 1594. Public Record Office, Exchequer Depositions by Commission, 39 Eliz., Hil. 23. British Museum, Lansdowne MS. 76.

[2] Gloucester, County Record Office, *D*421/*T*22.

[3] H. R. Schubert. *J. Iron Steel Inst.*, 1947, vol. 155, p. 524.

[4] Public Record Office, State Papers Relating to Ireland, vol. 228, No. 73*A*. Abstract: Calendar of the State Papers Relating to Ireland, 1608–1610, p. 419: 1874. London.

successful business man, estimated the expenses at least three times as high.[5]

Perhaps the large capital required induced the King to leave the financial burden to a man wealthy enough to bear it. This man was William Herbert, Earl of Pembroke. The Earl not only had vast possessions in the bordering county of Monmouthshire and in South Wales; he also had a considerable interest in the Forest of Dean, as he held the office of Constable of the Castle of St. Briavels "*with the keeping of the deer and woods there.*"[6] On 17th February, 1612, he obtained a Royal grant of St. Briavels and the Forest of Dean with power to erect furnaces and forges, to take up 12,000 cords of wood per year for charcoal burning at 4*s.* per cord, and to dig iron ore and cinders.[7]

Subsequently, four furnaces were erected: Cannop and Park or Parkend in the centre of the Forest, Soudley on the eastern border, and Lydbrook. In addition, three forges were built at Parkend, Soudley, and Lydbrook. Building commenced immediately after the grant, and 1200 loads of timber were used for the erection of the works, including the necessary houses for workers and for storing charcoal and iron. The delivery of the 12,000 cords of wood granted to the Earl of Pembroke for charcoal burning started at the same time. The names of the four furnaces with three forges annexed are evident from accounts of timber delivered to them in the years 1614–1617.[8] Three of the ironworks were situated in an almost straight line across the Forest, from Ross on the Wye to Lydney on the Severn. They were (from north to south): Lydbrook (furnace and forge), Cannop (furnace), and Parkend or Park (furnace and forge). The fourth furnace (with a forge) was Soudley, the site of which was farther to the east, between Blakeney and Cinderford.

By an agreement of 3rd May, 1615, the Earl of Pembroke made over his lease to Sir Basil Brooke, who is known in history as a producer of excellent steel.[9] Sir Basil, however, worked only two of the ironworks, Parkend and Soudley, in partnership with Robert Chaldecott; Lydbrook and Cannop were operated by Richard Tomlins and George Moore, the latter apparently identical with the steward of Goodrich Castle in 1609 (*see* above). Each of the two groups of ironworks was supplied with half of the 12,000 cords per annum granted formerly to the Earl of Pembroke.[10] The separation into two groups did not last more than six years. On 6th April, 1621, all the ironworks within the Royal demesne of the Forest were leased to Philipp Harris and to Richard Challoner, a merchant of Bristol.

During the years 1628–29, two more forges were erected, one at Whitecroft, between Parkend and Lydney, the other at Bradley, near Soudley.[11] From this date onwards the Crown owned four furnaces and five forges in the Forest of Dean. Some of the works which were leased to Sir Basil Brooke, George Mynne, and Thomas Hackett in 1627 were rather old and somewhat decayed and caused considerable expenses for repairs and rebuilding. In 1635, when he applied for a new lease, Sir Basil estimated the expenses he had incurred up to then for building and repairing at £14,000.[12]

An inventory of the works taken in September, 1635 (*see* page 155), disclosed extensive building during the years 1631–34, but in spite of that all the ironworks, including the newly erected forges, were in a more or less poor state of repair in 1635. Probably it was this state that induced the Crown to turn down Sir Basil's application, and to lease the ironworks to Sir Bainham Throckmorton of Clowerwall (*i.e.*, Clearwell, north of St. Briavels), Sir Sackville Crowe, of Langhern in Carmarthenshire, and two Bristol merchants, John Taylor and John Gonning the younger, for 21 years commencing 24th June, 1636. To save timber, not more than two furnaces and four forges, or three furnaces and two forges, were to be operated at the same time. The lease gave the four partners the exclusive right of producing iron within the Royal demesne of the Forest. All non-licensed ironworks erected in addition to the King's works, including 'footeblastes' (primitive bloomeries with bellows worked by foot which apparently still existed in the Forest), should be pulled down. Sir Bainham and the other three lessees, who evidently were silent partners, had equal shares in the profits, but Sir Bainham got into debt with the two Bristol merchants in the course of the next four years. The mortgages he took from them at 8% had to be repaid out of his share of the profits.[13]

In 1640, the partners had to surrender their lease because the whole Forest with all the ironworks and mines was leased to Sir John Wynter of Lydney, principal secretary to Queen Henrietta Maria, wife of Charles I. The lease dated 20th February included extensive rights such as the liberty to erect new towns and villages. It was, however, arranged that Wynter should demise the two furnaces at Parkend and Soudley and the four forges of Bradley, Parkend, Soudley, and Whitecroft, with sufficient supply of wood and ore, to Sir Bainham Throckmorton and his partners as undertenants for six years. As Wynter already owned furnaces at Gunn's Mill, Lydney, and Rodmore, situated in a semi-circle around the eastern and southern borders of the Forest, he practically obtained control of almost the whole iron production

[5] Public Record Office, State Papers Relating to Ireland, vol. 229, No. 142. Abstract: Calendar, *loc. cit.*, p. 530.

[6] Rhys Jenkins, *Trans. Newcomen Soc.*, 1925–26, vol. 6, p. 48.

[7] Public Record Office, Chancery Forest Proceedings, Bundle 34.

[8] Public Record Office, Exchequer Special Commissions, No. 3837. *See also* Grant concerning delivery of wood for the erection of ironworks in the Forest, 26th March, 1612. Calendar of State Papers Domestic, James I, 1611–18, p. 125: 1858, London.

[9] Rhys Jenkins, *loc. cit.*, pp. 49–50 (also referring to the various leases between 1615 and 1636).

[10] Public Record Office, Exchequer Special Commissions, No. 3837.

[11] Public Record Office, Exchequer Special Commissions, No. 5304.

[12] Calendar of State Papers, Domestic Series, of the reign of Charles I, 1635–36, p. 309, London, 1865.

[13] Ipswich, East Suffolk County Record Office, North Family Manuscripts.

[14] Gloucester, County Record Office, *D*421/*T*23*A* and *B*.

in the Forest and its vicinity.[14] This position lasted only a few years. In the Civil War, Wynter, who was an ardent Royalist, was attacked by the forces of the Parliament, under the command of Major-General Massey, and all the ironworks controlled by Wynter were destroyed in 1644.

After the war, the former Royal ironworks in the Forest remained in ruins, but in 1653 the Council of State gave orders to a Major Wade to repair one of the old furnaces and also to build a new one. He subsequently obtained permission to build one furnace only, which was erected near the ruins of the former Parkend furnace but lower down the stream towards the village of Parkend. This second Parkend furnace was completed in January, 1654, and in the following winter a new forge was erected at Whitecroft.[15] Both were owned by the State, and their subsequent operations were controlled by the Government. After the restoration of the monarchy in 1660, the works became Royal property and were worked until 1662 by managers employed by King Charles II, but apparently with losses, as wages earned by miners and woodcutters were not paid.[16]

By this time the works at Lydbrook had been rebuilt, as in 1662 two furnaces, Lydbrook (called Howbrook furnace) and Parkend, and their forges, were demised to Francis Finch and Robert Clayton, a "scrivenor" of London for 11 years. Sir John Wynter, whose estates were restored, also had a share in these works and was allowed to have a part of the stocks worked for him. From 1st November, 1663, the two furnaces were operated for the next seven months by Clayton alone. When Finch and Clayton's lease expired, in 1673, the Treasury Board recommended the suppression of the works because of the "destruction of wood and timber" in the Forest. They were sold for demolition to Paul Foley.[17] Lydbrook was the only one of the former Royal ironworks where operations were taken up again in the early eighteenth century; at Parkend and Soudley, furnaces were not erected before 1799 and 1837 respectively.[18]

INVENTORY OF 1635

A detailed survey representing the state of the King's four furnaces and five forges is supplied by an "Inventory, Taken 24th–28th September, 1635," on the occasion of their lease to Sir Bainham Throckmorton and his partners (*see* footnote 13). An abstract of the inventory was published (H. G. Nicholls, "The Forest of Dean," pp. 272–277: 1858, London), based on a copy of about 1780, but it contained many substantial errors. For this reason, it appears worth while publishing the full text from the original documents.

[15] Public Record Office, Council of State, Order Book, vol. 70, p. 289; State Papers Domestic, Interregnum, vols. 62, fol. 67, and 130, fol. 188.

[16] Rhys Jenkins, *loc. cit.*, p. 54.

[17] Gloucester, County Record Office, *D*421/*E*6, British Museum, Stow MS. 498. Rh. Jenkins, *loc. cit.*, pp. 54–55.

[18] B. L. C. Johnson, The Foley Partnerships, Economic History Review, second series, vol. IV, p. 324; Rhys Jenkins, *loc. cit.*, p. 61.

The first of these documents (subsequently referred to as document *A*) was found with other papers of Sir John Bankes, Attorney-General from 1634 to 1640, at Lydney Park, in Gloucestershire, in 1949. The Bankes' papers were transferred to the County Record Office at Gloucester, and subsequently to the Bodleian Library at Oxford, where they are at present. Document *A* (Bankes Papers 5/50) is the original draft examined and signed by Charles Harbord, Surveyor General, who headed the Commission set up with the object of making the inventory.

The second document (subsequently referred to as document *B*) evidently was the copy of the inventory which was annexed to the specimen of the lease given to John Gonning, of Bristol, one of the partners. It is now among the Records of the Gonning family which constitute a part of the North Family Manuscripts, preserved at present at Ipswich, East Suffolk Record Office. Document *B* is a copy of document *A*, but with one main difference, *viz.*, the section dealing with Soudley Forge is placed between the sections dealing with Parkend and Whitecroft forges in *B*, but at the end of the text in *A*. Occasionally there is a misreading in *B*, *e.g.*, the figure indicating the extension of timber building at the hutch of Parkend furnace is "14" ft. in *A*, but this number is blotted and difficult to read, and it is replaced in *B* by "16" ft., *i.e.*, 2 ft. too many. Further, in the inventories of the forge implements a clearer distinction between chafery and fineries is made in *A*. For these reasons, this publication is based on *A*, but variations in *B* are referred to in the footnotes.

The text of the inventory is as follows:

Forest of Deane[a]. *An Inventorie of his Ma.*[ts] *Ironworkes in the said Forest with the implements belongeinge to the same, taken the 24th, 25th,* 26, 27 *and 28th of September* 1635 *by Charles Harbord Esq.*[a] *his Ma.*[ts] *surveyor general, James Kyrle and Charles Bridgman Esqs. and others, by virtue of his Ma.*[ts] *Commission under the seale of the Exchequer dated* 17[b] *Junij last past to them and others directed in that behalfe.*

Lydbrooke fornace *built about* 3 *yeares since,* 23 *foot square at the bottome and* 23 *foot deepe, much crackt, in the front whereof is* 1 *sowe of yron and* 2 *sowes over the tewyron.*

The water wheele 23 *foot diameter, new made about one yeare since, on the shafte whereof are* 6 *iron hoops,* 2 *gudgeons and* 2 *brasses: in good repaire.*

The bellowes open, with leathers, nayles, girt(es), and irons.

A stone butteresse 10 *foot square behind the fornace to strengthen it.*

The fornace house 92 *foot about, the walles thereof of stone* 10 *foot highe, roofed over and tyled.*

A peece of wall to support the bridge of the fornace, 22 *foot longe,* 11 *foot highe, with a halfe wall adioyninge, to keepe up the banke,* 19 *foot longe and* 6 *foot highe.*

The bridgehouse 21 *foot square,* 8 *foot highe in sydewall, the bridge double plankt, the roofe uncovered, built one yeare since.*

The fence walls thereunto 10 *foot highe, made of tymber and wattle.*

(*a*) Omitted in *B*. (*b*) In *B*: the XVIIth.

The trough[c] *leadinge the water to the wheele 33 foot longe close, and 50 foot longe underground.*

A myne kilne[d] *defective, with 6 peeces of cast iron in the draught holes, of about 5c weight, built about 4 yeares since.*

In the fornace watercourse, at the waste, a trowe 22 foot longe, 2 foot square, open and borne by 2 peeces of wall, whereof one[e] *16 foot longe and two foot and halfe thicke, the other 15 foot longe and 7 foot thicke.*

The hutch leadinge the back water from the wheele, not made by theis[f] *farmers, 30 foot longe, 8 foot deepe.*

A founders house, of tymber and wattle, tyled, with a dormer and a stone chimney, floored all over, 32 foot longe, 16 foot broad and ten foot in sydewall, built about 20 yeares since.

Three poore thatched cottages whereof one built by the present farmers.

Implements of Lydbrooke fornace

Longe ringers	4	*synder hooke*	1
short ringers	4	*stopper*	1
synder shovels	4	*buckstaves*	2
sledge[g]	1	*dam plate*	1
cole rakes	2	*Wheele barrowes and baskets enoughe to furnish the worke.*	
handhammer	1	*Colliers hurdles in the woods*	
placket	1	*a sett of iron cambes.*	
gage	1	*A new paire of bellowe*[h]	
A woodden beame with iron chaines, triangles and weight of raw iron	10c	*bords, readie sawed.*	

The repaire of the fornace to make it fit to work (as it is estimated) will cost about fiftie pounds.

Cannop fornace, *now bloweinge, built for the most parte and the rest repayred by the now farmors about foure yeares since, 22 foot square at the bottome, in the front whereof are 4 sowes of iron and 3 sowes in the tewyron wall.*

The wheele 22 foot diameter, on the shafte whereof are 7 iron hoops, 6 iron cambes weyeinge about IV[c]*, 2 gudgeons and brasses, all in good repaire, and new made about 3 yeares since.*

The fornace house built of tymber by the said farmors about 4 yeares since, in repaire.

The bridge house 48 foot longe 21 foot broad and 9 foot highe in sidewalls, built about 2 yeares since, the bridge built about 4 yeares since, covered with bord(es) and bottomed with planke.

A trowe leadinge the water to the wheele, cut out of whole tymber and ledged on the top, 1 foot broad at the bottome, and 1 foot and a quarter deep, and 225 foot longe, new made about 4 yeares since and now in repaire.

The hutch leadinge the water from the wheele, 5 foot square, 85 foot longe.

The fornace keepers cabin built of tymber by the present farmors and covered with boards.

A cottage neere the said fornace built by the workemen of that fornace, now enioyed by the filler there, and not belongeinge to the said workes.

A house wherein the clarke of the said fornace dwelleth, with a little stable adioyninge, built by the present farmors.

A house adioyninge to the clarkes house, now inhabited by the founder.

A cabin for the myne cracker.

A myne kilne not in repaire wherein are 5 pigs of iron.

Implements of Cannop[i] *fornace*

The bellowes furnished, defective in the leathers		*buckstaves*	2
water trowes	3	*tewyron hooke*	1
grindestone	1	*iron tempe*	1
longe ringers	10	*cinder plate*	1
short ringer[k]	1	*dam plate*	1
constable	1	*wheele barrowes*	4
mouldinge ship[l]	1	*great sledge*	1
castinge ladles	2	*tewyron plate, cast*	1
cinder hooke	1	*tunnel plate*	1
placket	1	*gage*	1
cole baskets	12	*A crackt wooden beame and scales, with triangles furnished, and a tun of iron*	
myne hammers	2	*pigs used for a waight.*	
myne shovels	2	*Colliers hurdles*	8 dozen
cole rakes	2	*New firket*	1
myne rakes	2	*3C and an halfe of rawe iron upon the bellowes poizes.*	
boshes	2		
ladder of 14 rungs	1		

The[m] *repaire of the defects of this fornace will cost (accordinge to an estimate thereof) about seven pounds thirteen shillings and foure pence.*

Parke-end fornace. *The bodie thereof 22 foot square at the bottome, repayred by the present farmers about 4 yeares since, and the backer wall of the fornace and parte of the wall over the bellowes then built from the foundacion. In the front thereof two broken sowes of iron, and there hath been one more which is taken thence and is lyeinge neere the doore of the fornace house, and there are 2 sowes of iron in the tewyron wall.*

The fornace bodye and the bindeinge beames thereof crackt and insufficient to worke.

The water wheele 22 foot diameter with his shafte whereon are 7 iron hoops, 6 cambes, 2 gudgeons, and brasses, in repaire.

The fornace house built with stone 22 foot square and 9 foot highe in the side walls, the roofe good except one little breach by the bridge and tyled, built about 4 yeares since and now in repaire.

A penthouse under the fornace.

The bridgehouse 42 foot longe 22 foot broade the sidewalls 8 foot and halfe[n] *highe, covered with boards, double bottomed with planke upon stronge sleepers, with fence walls, built about 4 yeares since and in repaire.*

Trowes cut out of sound tymber 100 foot longe, covered with planke.

Another watercourse 2 foot and halfe broad, and 46 foot longe, built with stone on both sides and covered with planke, in which is a cast iron grate.

A watercourse on the north side of the said fornace about halfe a mile longe with a bay at the head thereof with a small breach therein, wants scowringe, otherwise good.

(*c*) *B*: trowe
(*d*) *B*: kill
(*e*) *B*: "one is 16 foot longe"
(*f*) *B*: these
(*g*) *B*: sledges
(*h*) *B*: bellowes; boards ready sawed.
(*i*) *B*: Canoppe
(*k*) *B*: ringers
(*l*) *B*: shippe
(*m*) In *A* this section is in a marginal note, but in *B* it is in the text.
(*n*) *B*: a halfe

A watercourse of about halfe a mile longe on the south side of the fornace.

The hutch 6 foot deepe, 3 foot broade, 70 foot longe, whereof 56 foot built of stone and 14[o] foot of tymber, all covered with planke and in repaire, but the streame stopped below the hutch with cinders.

A house enioyed by the founder.

A cottage adioyninge thereunto.

A cabbin for the bridgeserver 18 foot longe, 11 foot brode built of tymber and covered with boards.

A cabin adioyninge to the fornace for the fornace keeper.

A faire house 3 storyes highe, tyled, the ends built with stone and the rest with tymber, 50 foot longe, 16 foot broad, with a crosse building in it 16 foot square, with 2 stables of tymber belongeinge thereunto, in repaire.

A small cottage now enioyed by William Wayte.

The myne kilne decayed in the inside, and the pigs of iron taken from the draughts thereof.

Implements of Parke-end fornace

The bellowes open with the iron furniture belonging defective in the leathers		*wheele barrowes*	2
		myne hammers	2
		cole rake	1
buckstaves	2	*cinder rakes*	2
damplate	1	*great sledge*	1
cinder plates	2	*ringer hammer*	1
tewyron plate	1	*constable*	1
dam hooke or stopping hooke	1	*tunnel plate*	1
		grindstone	1
iron shovels	4	*new bellowes bords*	2
ringers	9	*old bellowes bords*	4
cole baskets	6	*collyers hurdles in the woods enough for the worke.*	
Beame with scales, hookes triangles and linkes with halfe a tun of rawe iron for a waite [p]			

The repaire of the defects in this fornace (accordinge to an estimate thereof made) will cost about threescore pounds.

Sowdley fornace

The body thereof 28 foot square at the bottome and 24 foot square at the top, in the front whereof are 4 sowes of iron, and 2 sowes over the tewyron, and foure longe bars of wrought iron to keep in the corner posts, in good repair, saveinge one small defecte in the inside of the fornace.

The water wheele 22 foot diameter, upon the shafte whereof are 7 hoops of iron, 6 cambes, 2 gudgeons, and brasses, in repaire.

The fornace house and penthouses made of stone 8 foot highe and 186 foot in circuit, tyled for the most part the rest boarded.

The bridge and bridge house decayed and parte of the bridge house fallen downe.

A coleplace 61 foot longe, 40 foot broad, whereof one side and the 2 ends are walled about with a wall 7 foot highe and 4 foot thicke.

A myne kilne wherein are 10 peeces of rawe yron, in repaire.

Five little cottages on the north side of the streame there.

The founders house built of stone 2 storeys highe, 20 foot longe and 14 foot broade, with a penthouse adioyninge covered with boards.

The trowes leadinge the water to the wheele 2365 foot longe much decayed.

A dam about a mile above the fornace, at Cinderford, 300 foot longe, 12 foot broad on the top, and 25 foot highe, faced and backed with turfe, with a ground goyte and a highe trowe thorowe[q] *the bay, with a fludgate*[r] *of three gates 36 foot longe, 12 foot broad and 6 foot deepe, with a little horsebridge over it, ranged with tymber and aproned*[s] *with planke.*

Another dam about halfe a myle higher on the same streame 720 foot longe with a sluce and a ground trowe, some what defective in the face thereof.

Implements of Sowdley fornace

The bellowes open the leathers halfe worne		*sledge*	1
		fornace shovels	8
longe ringers	3	*cinder plate*	1
constable	1	*dam plate*	1
short ringers	9	*tunnel plate*	1
dam hooke	1	*tewyron plate*	1
placket	1	*a beame scales and triangles*	
cinder hooke	1	*and 1000 pounds of rawe*	
gage	1	*iron for a waight.*	

The repaire of the said fornace (accordinge to an estimate thereof made) will cost about one hundred and thirtie pounds.

Lydbrooke Forge, consistinge of

One hammer and anvill, one chaferie, and two fineryes and 3 paire of bellowes furnished and workinge.

The house 42 foot longe, 32 foot broad covered with boards, built about 4 yeares since, in repaire.

The great hammer beame with the wheele, with 13 yron hoops, 2 great gudgeons and brasses of about 3[c] *of cast iron and 2 yron hoops about the anvill blocke.*

On the 2 fynery beames, 9 hoopes, 4 gudgeons and 4 brasses cast iron. On the chaferye beame, 4 hoops, 2 gudgeons and 2 brasses of cast iron.

In the chimneys 3 chimney bars of cast iron and 3 morris bars.

One hurst 2 boyts of cast iron 1 bray, 1 sett of hurst wedges and 2 wedges in the hammer eye of wrought iron.

One storehouse floored and tyled built of stone 18 foot longe, 13 foot wide, and 10 foot highe in syde walls, with a paire of stayers to the chamber.

One colehouse 30 foot longe, 24 foot wide, 11 foot highe in sydewalls, covered and syded with boards, with a shut[t] *house for brayes on the side thereof 8 foot broad, leaninge and defective.*

A court paled about with 76 foot of paleinge.

An old house on one side thereof.

The dam or bay with the wast and hammer gate and ground goyte defective.

A watercourse for the wast water 180 foot longe, 4 foot square, built about 6 yeares since with two ranges of tymber with sleepers and spreaders, and plankt at the bottome, defective.

A paire of new wast gates with stems, ready framed for the forefront and not set up.

One hammer mans house built about one yeare since of tymber with a stone chimney, 20 foot longe, 16 foot broad and 8 foot highe in sydewall.

(*o*) *B*: 16

(*p*) *B*: waight

(*q*) *B*: through (*r*) *B*: floodgate (*s*) *B*: approved (*sic*)
(*t*) *B*: shutte

Implements in Lydbrooke forge

Chaferie			
plates	5	*paire of great tongs*	1
tewyron	1	*paire of shinglinge tongs*	4
ringer	1	*cold chissels*	2
furgon	1	*handhammer*	1
quasse	1	*sledge*	1
iron dish	1		
2 *fineryes* [u]			
plates	10	*paire of great tongs*	2
ringers	2	*paire of small tongs*	2
furgons	2	*handhammers*	2
tewyrons	2	*cole rake*	1
quasses	2	*wheele barrowe*	1
iron dishes	2	*shovel*	1
clams	2	*baskets enough for the worke*	
an iron beame with scales and chayns, and c w(eigh)t of cast iron.		*a new hammer beame readye squared neere at hand.*	

The 2 fynery wheeles, the chafery wheele, the hammer beame, one of the fynery beames, the wast hutch, the juttie of the bay, the trowes and penstocks, the cole house and one workmans house are in decay, and the repaire thereof will cost (accordinge to an estimate made thereof) about fortie pounds.

Park end forge *consistinge of two hammers, 3 fyneryes and 1 chaferie which were generally repayred and parte new made about 2 yeares since.*

The lower part of the bay 120 foot longe 12 foot highe, made of tymber with sylls, laces and posts, the front of the bay where the water is lead to the forge, built of stone with 2 draweinge gates.

A fludgate[r] *of 6 sluces in the bay 44 foot longe and 22 foot broad strongly tymbred, and built on each side with a stone wall of 3 foot highe above the apron and 3 foote thicke, and aproned*[s] *with planke, 160 foot belowe the sluces.*

A storehouse for iron 24 foot longe 18 foot broad and 13 foot highe in sydewalls, whereof 3 foot of good stoneworke, built with tymber and tyled, with a convenient room over it and a paire of outside stayers leadinge thereto.

One faire colehouse 62 foot longe, 29 foot broad, and 17 foot high in sydewalls whereof 5 foot stoneworke and 12 foot tymber, 5 bayes, covered with boards, and 2 great paire of stayers unto it, built about 3 yeares since.

One coleyard inclosed within a wall 50 foot in circuit and 8 foot highe, with a great doore and hinges.

One old colehouse adioyninge.

One house built of stone for the colekeeper 23 foot longe and 17 foot broad, tyled, and conteyns 4 roomes.

One house built for the fyner 16 foot longe 15 foot broad and covered with boards.

One house for the hammerman lately repaired.

Two cottages enioyed by the fyners.

One little house adioyninge to the forge for the carpenter to worke in.

Implements in Parke-end forge

Forgeing hammer		*boytes*	2
hoops on the hammer beame	13	*bray*	1
gudgeons	2	*great wedges in the hammer eye*	2
brasses	2	*hoops on the anvil block*	2
great hamer	1		
anvill	1		
hurst, and sett of hurst wedges	1		

Shinglinge hammer on the beame thereof 10 iron hoops and all things else as the forgeinge hammer hath.

Chaferie			
	plates 5		
fixt	*morris plate of raw iron* 1	*paire of chafery bellowes furnished*	1
fixt	*morris bar of wrought iron* 1	*hammer bit*	1
	tewyron 1	*hammer eye*	1
	plates of cast iron over the tewyron 2	*paire of great tongs*	1
		paire of shinglinge tongs	7
fixt	*pig of iron over the tewyron* 1	*ringer*	1
	hoops on the chaferie	*furgon*	1
	wheele 4	*handhammer*	1
	gudgeons and brasses 2	*clams*	4
	brasse-iron to keep downe the shafte of the wheele 1	*iron dishe*	1
		quasse	1
	sledge 1	*loop plate of about 3 cwt.*	1
	shovel 1	*cold chissels*	2
	mandrill 1	*water trowes and anvill blocks.*	
The Upper Finerie			
	paire of bellowes furnished 1	*loope plate*	1
	hoopes on the wheele	*tewyron*	1
	shafte 4	*ringer*	1
	gudgeons and brasses 2	*furgons*	2
	plates 5	*quasse*	1
fixt	*chimney plate of* [v] *cast iron* 1	*iron dishe*	1
fixt	*morris barr* 1	*clam*	1
	pair of shinglinge tongs 1	*ringer hammer*	1
	pair of great tongs, or maudlins 2	*wheele barrowe*	1
	iron beame scales and hookes and 2c. of cast iron for a waight	*baskets and hurdles sufficient for the worke.*	

The 2 lower fyneryes have implements according to the upper fynerye.

The chaferye wheele, the front of the bay and some earth worke in the bay defective, the repaire whereof (accordinge to an estimate thereof) will cost about five and twentie pounds.

Wheatecrofte Forge. *70 foot longe and 28 foot broad, consists of two hammers, one chaferie and 3 fyneryes, built from the ground about 6 yeares since, and the lower parte thereof beinge burnt, rebuilt about three yeares since, in repaire and workeinge.*

The bay thereof[w] *460 foot longe, 26 foot broad between the stone walls which are 5 foot and an halfe in thicknes at the topps and about 13 foot and halfe highe about the middle and generally 8 foot and halfe highe above the grounde.*

In the bay 2 sluces or hammer gates, built with stone with 2 paire of tymber sluces to the same.

And one greate fludgate of 6 gates 37 foot longe 25 foot broad strongly built of tymber, aproned[s] *with planke and double planked on the sides, with a horse bridge made over it.*

One watercourse of tymber 143 foot longe 10 foot broad and 5 foot deepe, ventinge the water from the forge, planked on each side with sleepers at the bottom and spreaders at the top.

One storehouse 30 foot longe 16 foot and halfe[n] *broad 9 foote highe in sydewalls, covered with boards.*

(*u*) *B*: fynery

(*v*) *B*: & (*sic*)

(*w*) *B*: whereof

One great colehouse 58 foot longe 28 foot brode 17 foot highe in sydewalls whereof 5 foot from the ground built of stone, all the rest of tymber, covered with tyle, with 3 great doores and 2 paire of stayres on the outside thereof.

One other storehouse 15 foot square uncovered.

One house 2 storyes highe 34 foot longe, 17 foot broad the pine ends thereof stone, the rest tymber, tyled over.

One house for the clarke, built of tymber 2 storeys highe 24 foot longe and 15 foot broad, with 3 dormers, with a garden and a courte paled about.

One fyners house adioyninge,

Three other fyners houses thatched.

The implements and furniture of this forge, accordinge to the forge at Parke end.

The bay, the wheeles, plummer blocke, hutches and some other parts thereof are defective, the repaire whereof (accordinge to an estimate thereof) will cost about thirtie pounds.

Bradley Forge. *70 foot longe and 31 foot broad consistinge of two hammers, three fyneryes and one chaferie, built from the ground about 6 yeares since, and now workeinge. And for the parts thereof and the implements used therewith, is agreable to the forge at the Parke end.*

The dam is 183 foot longe, 20 foot broad between the stonewalls, which are 3 foot thicke on the top and 18 foot highe about the middle of the dam.

In the dam a fludgate[x] of 4 gates, 20 foot longe 18 foot broad aproned[s] and covered with planke for a bridge, with a[x] carriage for the water 76 foot longe 18 foot broad walled on each side and piched with stone in the bottom with a fall at the end thereof made of tymber 36 foot longe and 18 foot broad.

The rest of the sluces and hutches, as in the forge at the Park end.

One colehouse of 6 bay, of stone buildinge and tyled, 60 foot longe 28 foot broad and 16 foot highe in sydewalls, without doores, but hath a court 35 foot longe 26 foot broad walled about with a wall 7 foot highe with doores.

The clarkes house built of stone, 3 storyes highe and tyled, is 56 foot longe, 20 foot broad with a crosse buildinge 19 foot square.

Foure workmens cottages thatched.

There are 2 new hammer beames readie made, lyeinge under the wall of the colehouse courte.

The wheeles, shafts, shinglinge hammer beame, tyleinge of the colehouse, hutches and plummer blocks, scales and bellowes defective, the repaire whereof will cost (accordinge to an estimate thereof) about one hundred pound(es).

Sowdley Forge.[y] *42 foot longe, and 30 foot broad, consistinge of one hammer and anvill, one chaferye and two fyneryes new built in the place of a decayed forge there, about two yeares since. The parts and implements whereof are accordinge to the forge at Lydbrooke.*

One store house adioyninge to the forge 16 foot square with a roome over it, built of tymber and covered with boards.

One cole house 36 foot longe, 27 foot broad, 9 foot highe in the side walls, with a dormer, and covered with boards.

In the dam a new fludgate in the place of one that the fluds carryed away, of 6 gates, 94 foot longe and 10 foot broad, aproned[s] with planke and cheeked with stone.

The wheeles groundsills trowes penstocks and some other parts thereof defective, and the repaire thereof (accordinge to an estimate made thereof) will cost about threescore pounds.

Memorandum that the now farmers Sr. Bayneham Throckmorton and his partners are not to be charged by this inventory with anie of the implements of Whyte Croft double forge and Bradley double forge which are not fixed to the freeholde, bycause those two forges were erected and made by the late farmers Sr. Basill Brooke and Mr. Mynn, of whome the newe farmers are to buye all the moveable implements and furniture of the same as they shalbe apprised and valued indifferently betwene them.

C. Harbord[z]

The first part of the inventory deals with the furnaces, the second part with the forges.

THE FURNACE

The ruins of one of the furnaces erected in 1612 were discovered in making an excavation in the Forest about 140 years ago. The celebrated ironmaster David Mushet, a native of the Forest of Dean, saw the remnants and described the site as being below York Lodge.[19] Judging by the position, it doubtless was the Parkend furnace referred to in the inventory of 1635. Hearth and boshes of the furnace were found complete. They are shown in Fig. 1, supplied by Abraham Rees in 1820, with an explanatory text.[20]

(*x*) Omitted in *B*.

(*y*) In *B* the whole section concerning Soudley forge is placed between the sections on Parkend and Whitecroft forges.

(*z*) The signature is omitted in *B* and replaced by: *per ℔re de privato sigillo etc.*

[19] D. Mushet, "Papers on Iron and Steel," p. 387: 1840, London.

[20] Supplement to the fourth, fifth and sixth edition of the *Encyclopaedia Britannica*, Plate LXXXVIII, figures 5–7, Edinburgh, 1820, and vol. V, pp. 124–125, Edinburgh 1824.

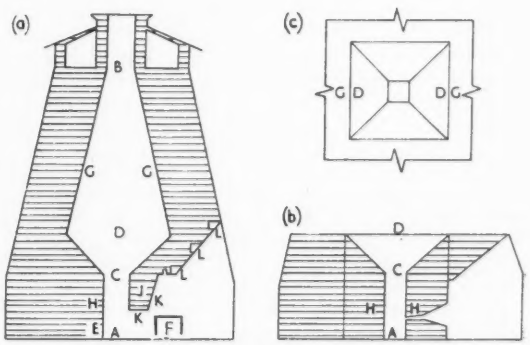


Fig. 1—Sections through the first Parkend furnace

Figure 1*a* is a cross-section of the stack of the furnace made through the aperture which served for tapping the molten iron. The outer casing or shell, termed the body of the furnace in the inventory, had a basement 22 ft. square, the outside walls of which rose almost vertically to the height where the hearth joined the boshes (*C*), which was 5 ft. from the ground. The upper part placed upon this basement resembled a truncated pyramid with a slight incline downwards. The incline of Soudley furnace, which was the largest of the King's four furnaces, is indicated by the description of the stack as 24 ft. square at the top and 28 ft. square at the bottom.

Both the vertical basement and the height of the stack, which varied from 22 to 24 ft., indicate that a development of the English furnace had taken place within the period of about 120 years, following the introduction from France shortly after 1490. Emanuel Swedenborg, who as a young man was in England from 1710 to 1712 and visited furnaces in the district of Stourbridge in the Midlands, remarked on the outer casing or shell being different from those of other countries, as the outer walls were parallel, *i.e.*, vertical, from the bottom up to one-third of the total height and then converging.[21] If he had been in the Forest of Dean, he would have noticed the same peculiar shape.

Unfortunately, there is no evidence of the dimensions of the English furnace before the inventory of 1635. However, some conclusions may be drawn from the countries, such as France and Belgium, in which this type of furnace originated. As late as 1775, the height of the French blast-furnace generally was 17–20 ft.,[22] and in Belgium it did not exceed 17 ft. before 1800.[23]

From this it may safely be concluded that the earliest English blast-furnaces were about 17 ft. high or less. The height of 22–24 ft. referred to in 1635 therefore represents a remarkable improvement.

The shell of the furnace was supported by a stone buttress which, at Lydbrook, was 10 ft. square. A further support was supplied by a framework of strong wooden beams embracing the outer walls at certain intervals. They are the "*bindeinge beames*" of the furnace at Parkend. Such beams are shown on an ornamental fireback of 1636 representing a Sussex furnace.[24] They were intended to prevent cracks in the walls caused by a combination of moisture from rain or snow and the heat penetrating from within. A further device to prevent the effect of moisture (not depicted in Rees' drawings) was the "*penthouse under the fornace*" at Parkend; this was a chamber built underneath the bottom stone to collect ground moisture.

The body of the furnace was built of large stones cemented together with mortar. The inner lining (*GG*), according to Rees, was constructed of a "*thin bed of an infusable species of sandstone.*" There was a space left between the lining and the outer walls which generally was filled with sand.

The hearth (*H*) was "*composed of stronger beds of the same species of sandstone, called land-stone.*" The hearth was 4 ft. high (from *A* to *C*), and 4 ft. wide from the backwall (*E*) to the front of the dam stone (*F*). There was an aperture in the front of the furnace where the founder worked. The arch closing the top of it was strengthened by sows of cast iron (*L*), placed into the ceiling of the arch at intervals and frequently referred to in the inventory. The stone at the very back of the arch towards the hearth was the tymp stone (*J*), protected underneath and outside by the tymp plate (*K*, iron tempe in the inventory). Each side of the aperture between the tymp stone and the bottom was protected by a vertical iron plate, termed a buckstave. The dam stone was covered with an iron plate, called the dam plate, with a notch on the top through which the cinder or slag ran off, upon the cinder plate. If the cinder coagulated, it was hauled out with a cinder hook. To make room for fresh cinder, the cinder plate was cleared with rakes and shovels. On one side of the dam stone there was another notch or a slit mostly closed with clay. It was opened by piercing the clay with a long iron bar (termed a ringer) whenever the molten iron was tapped. The iron ran into a furrow made in a bed of sand by a moulding ship. If it ran off too vehemently, it was held back by a stopper or dam hook, also termed a hardew. For casting small objects, such as bullets or pots and pans, the molten metal was ladled out with casting ladles and poured into moulds. Ringers were the implements most frequently used in the smelting process, which accounts for the large number. They were either hooked or pointed, the points being sharpened on grindstones. When too hot, they were cooled with water in troughs, termed boshes. The ringers also served for scraping sidewalls and corners of the hearth to break off crusts which had formed there. These, when broken off, rose to the top of the liquid mass where they melted and deposited their iron contents. The strongest and longest bar (about 8–9 ft.), used for cleaning the hearth, was termed a constable.

Figure 1*b* is a cross-section through the other side of the hearth, where the second or tuyere arch was situated. This arch also was supported by iron bearers and had an opening into the hearth by which the blast entered through the tuyere. The tuyere, which was protected by the iron tuyere plate, contained the nozzles of a pair of bellows. The tuyere was fixed in clay with the help of a kind of trowel, termed a placket. A tuyere hook served for clearing the tuyere from slag which tended to adhere to it. The leather bellows, on the upper lids of which square pieces of timber, termed firkets, were laid, were pressed down alternatively by iron cams fixed on a rotating shaft or beam moved by a water wheel of 22 ft.dia. The shaft turned on cast-iron gudgeons or centre-pins fixed on the two ends of the shaft and running on brasses also of cast iron. The bellows were lifted by wooden beams or poles, termed poises or counter-

[21] E. Swedenborg, "De Ferro," p. 155: 1734, Dresden and Leipzig. G. Trobridge, "Swedenborg, Life and Teaching," pp. 19 and 24: 1935, London.

[22] P. C. Grignon, "Memoires de Physique sur l'art de fabriquer le fer," p. 110: 1775, Paris.

[23] H. Scrivenor, "History of the Iron Trade," p. 240: 1854, London; E. de Laveleye, *Proc. Inst. Mech. Eng.*, 1883, p. 331.

[24] H. R. Schubert, *J. Iron Steel Inst.*, 1952, vol. 170, Feb., p. 109.

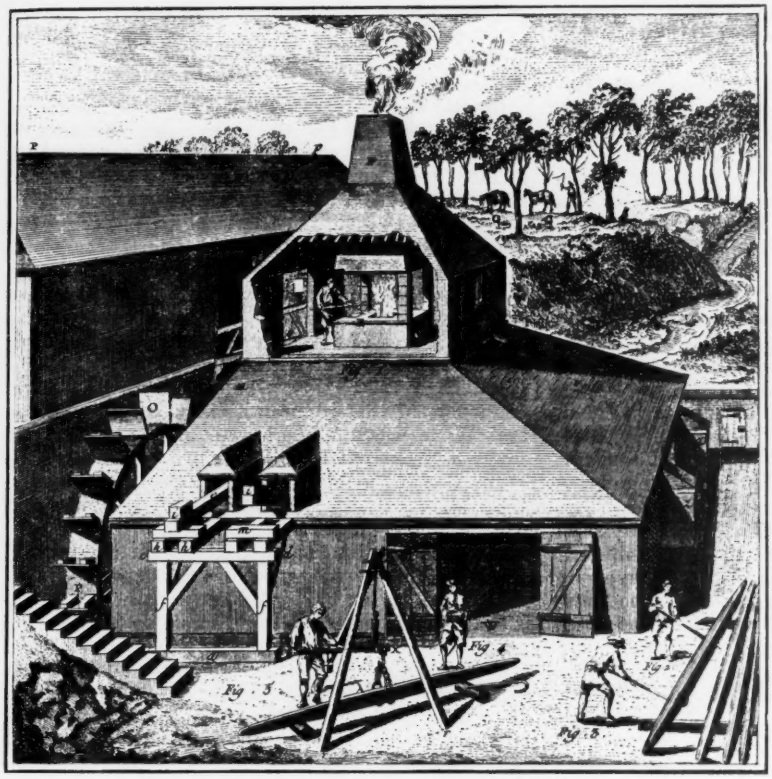


Fig. 2—An eighteenth-century furnace plant

poises, weighted with pieces of iron on their longer ends ($3\frac{1}{2}$ cwt. at Cannop) and working as levers.

Figure 1*c* is a horizontal section of the furnace at the top of the boshes (*D*), which were $2\frac{1}{2}$ ft. high, from *C* to *D*. It shows "*the quadrangular form of the interior which was common to charcoal furnaces at that time*" (Rees).

Figure 2 shows a French furnace plant of the 18th century which was similar to the English plant. The furnace was inside the furnace house which surrounded it on two or three sides and which is frequently mentioned in the inventory of 1635. On the top was a "*penthouse*," which protected the filler who put the charge into the top aperture, the wall of which was covered with an iron tunnel plate. The filler used a gage, an iron implement similar to a flail, to measure how much the charge had subsided. The charge was wheeled with a barrow across a bridge from the bridgehouse in which sufficient quantities of ore and charcoal were stored to safeguard uninterrupted feeding of the furnace. The ore was roasted in mine kilns. In the front of the furnace is a wooden triangle with scale, link and chain to weigh the sow which, when cool, was dragged out of the furnace house with the help of a sledge.

THE FORGE

The older type of forges consisted of two fineries, one chafery, and one power hammer. In the finery the pig iron obtained from the furnace was refined, *i.e.*, decarburized and freed from impurities, and in the chafery the refined iron was reheated in order to be consolidated and shaped into bars by the power hammer. To obtain a higher output, a new type of forge was introduced in England after 1600; this had three fineries, one chafery, and two power hammers. Both types are represented in the inventory of 1635. The process of refining, as well as reheating, was conducted in hearths. Each hearth was surmounted by a chimney supported by a morrisbar (derived from the French *marâtre*) over the front of the aperture where the forgeman worked. Bottom and sides of the fireplace of the hearth were covered with cast-iron plates. The iron was worked with ringers or furgons which were a kind of lever used to raise the iron in order to expose new surfaces to the decarburizing blast. When the fire burnt too vehemently, it was stopped with a quass. Tongs were used for taking the lump of purified iron out of the hearth and holding it on the anvil. The great tongs, also termed maudlins, were held together with clams. Hand hammers or sledge hammers were small wooden hammers with which the refined lump (termed a loop) was beaten on a loop plate to knock off the slag covering the surface, before the loop was dragged to the power hammer. Iron dishes were vessels containing water for the cooling of implements, anvil, or hammer head. A mandrill was an axe by which the half-finished product (termed a bloom) was cut into two halves which later were elongated into bars by the power hammer. The first application of the power hammer was termed shingling. Chisels of steel were used for cutting off the rough ends of the finished bar.

PRODUCTION

Very little evidence of the duration of campaigns and the output is available for the furnaces in the Forest of Dean in those early days. Of various statements made at Coleford, on 18th January, 1626, that made by William Browne, the founder at Lydbrook from June 1621 onwards, is the most reliable. From this date until 1625 inclusive, four campaigns took place at Lydbrook, lasting about 20, 26/27, about 30, and 49 weeks and "upwards." In the first three of these campaigns an average of 13 tons per week was produced, *i.e.*, 1 ton 17 cwt. 16 lb. per 24 hr. Browne further deposed that at Cannop furnace only two campaigns had taken place within the same period, the first continuing for about 20 weeks, with a production of 253 tons, and the second for 19 weeks, producing

247 tons. These figures give an average output of approximately 1 ton 16½ cwt. per 24 hr. In the last campaign at Lydbrook, apparently in 1625, a total of 720 tons, within 49 weeks as a minimum of duration, was produced, *i.e.*, approximately 2 tons 2 cwt. per 24 hr.[25]

These output figures were similar to those of other iron-producing districts. In Yorkshire, at the furnace of Rievaulx, *e.g.*, the average duration of a campaign between 1610 and 1624 was 18½ weeks (varying from 12 to 21 weeks 5 days). The average production of a campaign was 253 tons 1½ cwt., or approximately 2 tons per 24 hr.[26] Unfortunately, no figures are available for almost 30 years following. The upward trend indicated by the last output of Lydbrook, however, suggests that progress had started in 1625.

In the accounts of the second furnace at Parkend, output figures are supplied from 28th February, 1654, when the first blowing commenced, to 17th January, 1660, which was the end of the last campaign referred to.[27] The references to the first two campaigns are too vague to allow safe conclusions. There is no statement indicating in which of the two campaigns the 701½ tons of shot and bullets (for the Navy) were cast. More exact statements are made in the accounts of the next three campaigns, between 1657 and 1660, as may be seen from the following schedule:

Date	Duration	Total Output, tons	Output per 24 hr.
22 Apr.–30 Dec., 1657	36 weeks, 1 day	725	2 tons, 17 cwt. 35 lb.
21 Sept., 1658–6 Aug., 1659	45 weeks, 4 days	792	2 tons, 9 cwt. 73⅓ lb.
19 Aug., 1659–17 Jan. 1660	21 weeks, 4 days	462	3 tons, 1 cwt. 19½ lb.
Averages:	34 weeks, 3 days	659⅔	2 tons, 16 cwt. 5⅓ lb.

The level of output reached in 1660 compares favourably with the initial period of 1621–1625, and also with other furnaces in the vicinity, *e.g.*, Tintern, in Monmouthshire, first mentioned in a survey of 1651.[28] In a campaign of 67 weeks in 1672–73, a total of 1142 tons was produced, and in 1675–76 a total of 1034 tons within 61 weeks,[29] *i.e.*, 2 tons 5 cwt. 107 lb. (and a fraction more) and 2 tons 8 cwt. 29⅓ lb. respectively per 24 hr. The furnace at Rodmore, between Lydney and St. Briavels, probably erected in 1629, made about 15 tons per week, *i.e.*, approximately 2 tons 3 cwt. per 24 hr. in 1649.[30] There were even hopes for a still greater production at Parkend in 1662, where an output of 1248 tons per annum, *i.e.*, 3 tons 14 cwt. 32 lb. per 24 hr., was considered possible if a "*greater proportion of water*" could be obtained.[31]

Greater and more regular supply of water as motive power apparently was the main cause of increased output. When the second Parkend furnace was built in 1653, great care was taken over the water supply. Major Wade, who was responsible for the building, pointed out that the furnace "*will be one of the best watered furnesses in this nation.*"[32] A further improvement was the admixture of scrap iron to the charge. The proportion, however, was fairly small compared with the cinder added, *e.g.*, 16 tons 4 cwt. of scrap iron and 701 tons of cinder to make 701 tons of pig iron in 1656–57.[33]

In his lengthy correspondence with the Commissioners of the Admiralty, there is no indication that Wade, when he built the furnace, altered the shape or increased the height, so it may safely be assumed that the second Parkend furnace, erected in 1653–54, was similar in structure and size to the first one and to the three others erected in 1612. The only innovation pointed out by him was the supply of a greater volume of water to move the bellows.

The stronger air blast produced by a better supply of water must have led to attempts to increase the height of the furnace to obtain greater production. Henry Powle, who described ironworks and methods of smelting and forging in the Forest of Dean, in 1678, gave the height of the furnaces as "*near* 30 *f.*," and in a rather crude sketch he marked the height as "28 *foot.*" The most important innovation he mentioned was the circular shape of the inner cavity above the hearth "*much like the shape of an egg.*"[34]

It is not known at which furnace in the Forest area the change from the quadrangular to the circular shape of the tunnel and boshes commenced, nor at what date. It was perhaps one of the furnaces operated by Wynter, either at Lydney or at Lydbrook. Sir John Wynter had a scientific mind and was interested in the major problems which troubled the ironmaster in his day, such as the substitution of charcoal by mineral coal. In 1656, he experimented with "*charring seacole to burne out the sulphure.*"[35] However, the innovation took place somewhere in the Forest area after the Civil War and before 1678. Gradually it found its way into the other iron-producing regions of the Realm until, by the end of the eighteenth century, it had almost entirely superseded the older quadrangular shape used for the King's furnaces before the Civil War.

[25] Public Record Office, Exchequer Special Commissions, No. 5304. Browne's figures are confirmed by depositions of other witnesses.

[26] Iron accounts preserved at Belvoir Castle.

[27] Public Record Office, State Papers Domestic, Interregnum, vols. 130, and 157*B*; Exchequer Special Commissions, No. 6080.

[28] Aberystwyth, National Library of Wales, Badminton No. 1631.

[29] Figures of total output and duration kindly supplied by Mr. B. L. C. Johnson, M.A., of Birmingham University, from papers in possession of Major Foley at Stoke Edith.

[30] County Record Office, Ipswich, North Family MSS.

[31] British Museum, Harleian MS. 6839.

[32] Public Record Office, State Papers Domestic, Interregnum, vol. 62, fol. 67.

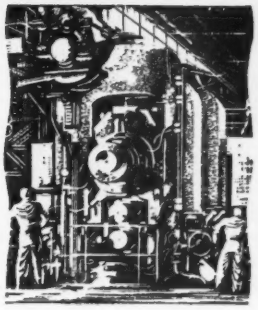
[33] *Ibid.*, 157*B*. Accounts of charcoal and ore were kept separately, but unfortunately they are not preserved.

[34] *Philosophical Transactions*, 1677–78, vol. 12, pp. 931–935, illustration *facing* p. 923.

[35] H. G. Nicholls, "The Forest of Dean": 1858, London. Sir John was first cousin to the Marquis of Worcester, the author of "The Century of Inventions," Rhys Jenkins, *loc. cit.* p. 51, note 14.

IRON AND STEELWORKS ENGINEERING

THE IRON AND STEEL ENGINEERS GROUP



Electric Distribution in Iron and Steel Works

By

T. B. Rolls, B.A., A.M.I.E.E., and E. C. Slater

PLANNING AND OPERATING THE INSTALLATIONS AT MARGAM AND ABBEY WORKS

SYNOPSIS

The paper briefly describes the problems involved in designing the electric distribution system of the Abbey, Margam, and Port Talbot Works of the Steel Company of Wales, Ltd. Although there was little choice in the selection of voltages and the type of equipment to be used, a policy of splitting up the load into manageable blocks has been pursued, thereby improving flexibility and minimizing the replacement of the switchgear. Operating and maintenance procedures are described, and particular mention is made of troubles associated with switchgear. 734

THERE have already been many excellent descriptions[1–4] of the electrical equipment at the Abbey and Margam Works of the Steel Company of Wales, Ltd. The present paper must, of necessity, be largely descriptive, but, so far as possible, an attempt has been made not to repeat what has already been published.

MAINTENANCE OF SUPPLIES DURING THE CONSTRUCTION PERIOD

When the decision was made to build Abbey Works and to extend Margam Works, two overhead transmission lines crossed the site. The first was a double-circuit 33,000-V. line, by which the principal supply from the Pyle sub-station of the South Wales Power Company (later the South Wales Electricity Board) supplied Margam and Port Talbot Works, and the second was a double-circuit 11,000-V. line, by which power was exported from Margam to supply Newlands and Aberbaiden collieries, which were operated by associated companies until they were vested in the Coal Board. In addition, part of the plan involved reconstructing Margam power station, so that little reliance could be placed on the existing generators (two 3000 kW. and one 6000 kW.). When work started, the load on the system was:

Margam Works	4 MVA.
Port Talbot Works	4 MVA.
Collieries	4 MVA.
Total	12 MVA.

A secondary 11,000-V. supply from a 6000-kVA. transformer at a third associated colliery, Bryn, reached Margam by an overhead line down the Ffrwdwyllt valley. This was not affected and was extended to supply most of the Port Talbot load.

At Pyle sub-station, a 10,000-kVA. transformer was installed to provide power at 11,000 V. for:

(i) Newlands and Aberbaiden collieries
(ii) Cornelly quarry, which was being mechanized to provide aggregate for foundations
(iii) Erection supplies to the south-east of Abbey by reversing the direction of power flow in part of the line from Margam to Newlands.

These arrangements did not include the 33,000-V. supply needed to keep Margam Works in production. The line could not stay where it was because of the civil engineering work that was to be carried out. A buried main was considered which would pass through several miles of built-up area on one side and thence into Margam through a zone where only moderate reconstruction work was expected, but this was rejected, not only because of the cost and way-leave difficulties, but also because of the difficulty of getting cable in time. The alternative route lay through sand dunes, across tide-washed saltings, and over a tip in which a gob fire was known to be burning; there was also one difficult crossing where a railway was to be reconstructed on an embankment. This route had to be adopted and two overhead lines were run, being carried over part of the route on double-circuit towers. One of these lines operated at 33,000 V. to

Manuscript received 1st December, 1952.
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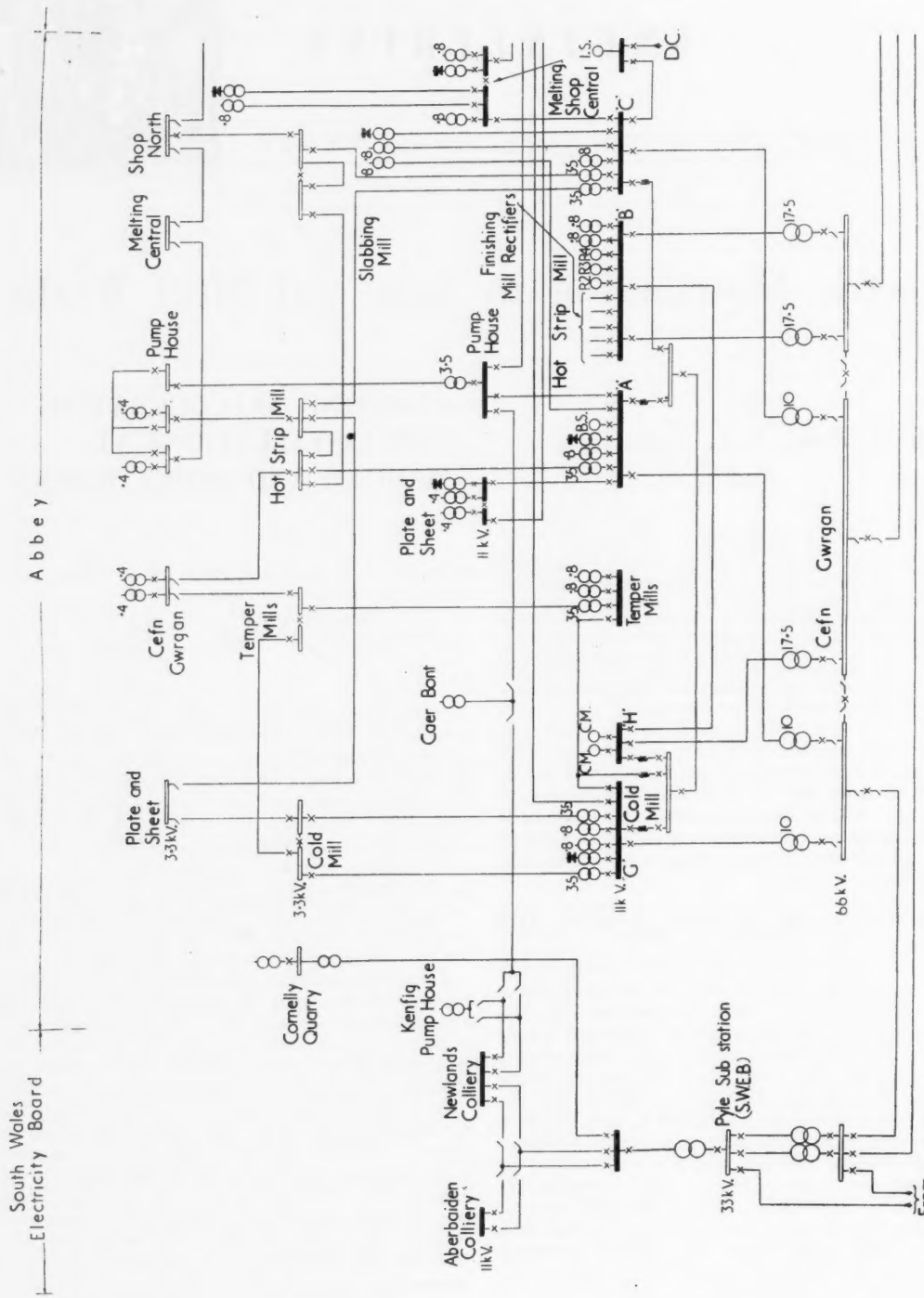


Fig. 1 (*left-hand*)—Distribution diagram of Abbey, Margam, and Port Talbot Works

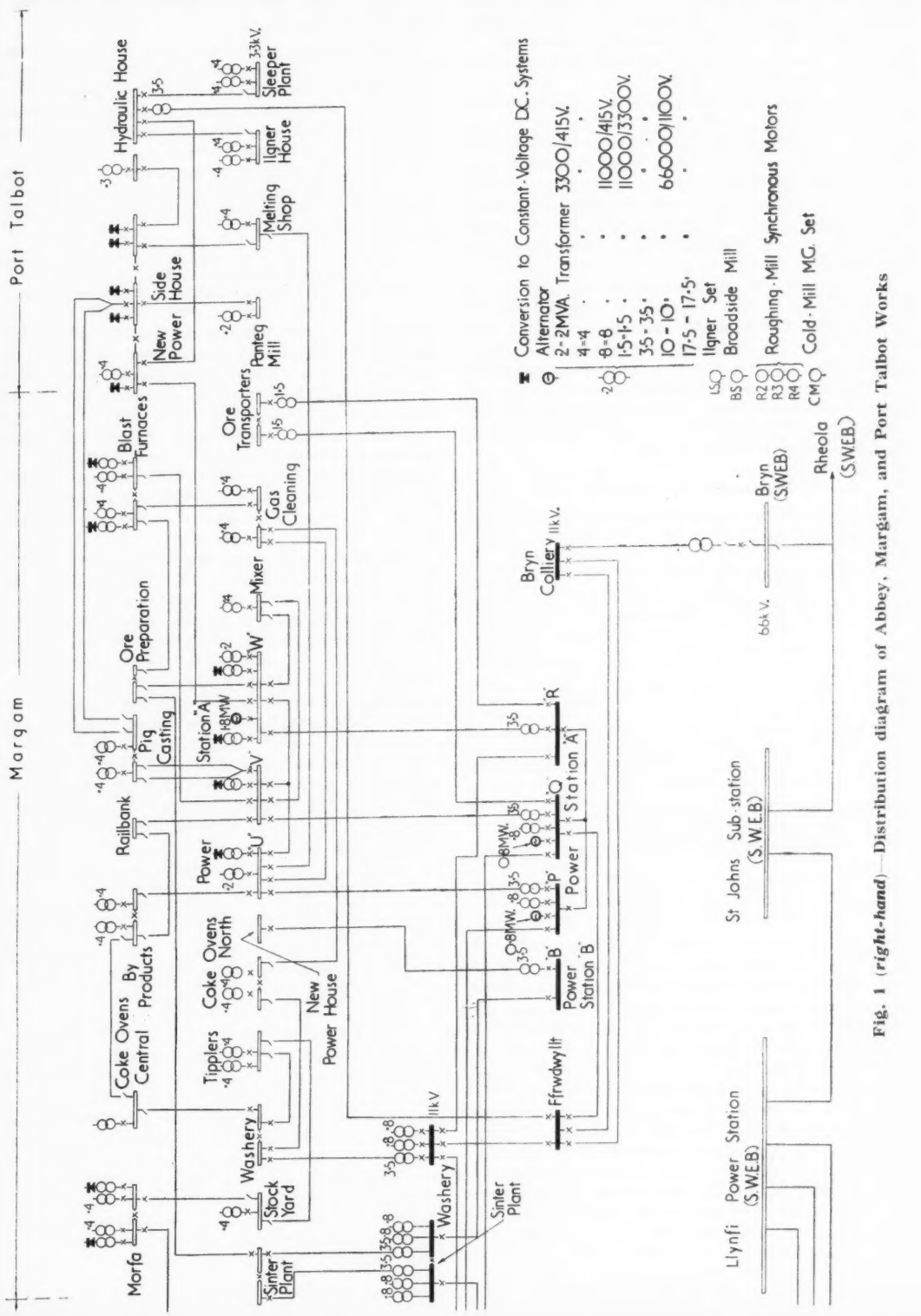


Fig. 1 (*left-hand*)—Distribution diagram of Abbey, Margam, and Port Talbot Works

Fig. 1 (*right-hand*)—Distribution diagram of Abbey, Margam, and Port Talbot Works

supply Margam; the second was an 11,000-V. line for erection supplies to the north-west of the Abbey site. Later it was possible to improve these lines so that they became the main 11,000-V. links between the Abbey and Margam Works.

These arrangements on the whole worked well, but so long as civil engineering contractors were on the site, the jibs of their cranes seemed to be irresistibly attracted to the overhead lines, despite the fact that the lines were sited so as to be as far out of the way as possible. Perhaps the worst stoppage was caused by the jib of a crane fouling an overhead line, while at the same time a bulldozer made an onslaught on a buried cable elsewhere.

A very complex changeover was carried out in Margam power house, where new or reconstructed high-voltage switchboards had to be put in new locations to free space for other purposes. Some difficulty was experienced in providing enough power at Margam during the later stages of this changeover, because the load created by new plant in Margam Works built up before the new generating plant in the power station was available.

SOURCES OF SUPPLY

The steelworks system has been supplied from the following sources:

(i) The mains of the South Wales Electricity Board at 66,000 V. at Cefn Gwrgan sub-station, with standby connections at 11,000 V. through Bryn and Pyle. When the system was planned, the collieries at Bryn, Newlands, and Aberbaiden were owned by associated companies, and it was intended to treat the supplies to the collieries as part of the steelworks system. With the creation of the National Coal Board, however, arrangements were made to supply the collieries independently, although the 11,000-V. interconnections through Bryn and Pyle have been retained as a mutual standby for use in emergency.

(ii) Generation at Margam power house. The following generators have been installed at Margam power house:
Two 8000-kW. mixed-pressure condensing sets
One 1800-kW. pass-out back-pressure set
One 3000-kW. condensing set (an old set retained for emergency use).

It is not intended in this paper to describe the steam side of this station beyond saying that the generators normally operate under pressure control, *i.e.*, they get what steam is left over after other users such as blowers have been supplied. Similarly, the boilers first take the gas required for the blowers and then, after other users have been supplied, absorb the remainder, which is available for electric generation. This means that the supply of electricity available from the generators is not reliable, but arrangements have been made to make the best use of the generators for supplying the vital steelworks loads (*e.g.*, pumping) when the Grid fails. The generators are connected to the amount of vital load that they are capable of supplying, and this is joined to the Grid through one interconnector. This is provided with directional over-current relays, which operate and leave the generators working on their own if excess current flows towards the Grid.

DESIGN OF THE DISTRIBUTION SYSTEM

General Considerations

Preliminary layouts of the plant enabled the main load centres to be located, and a general plan for the distribution system was formed. As details of the plant were settled, the arrangement of the distribution system was modified accordingly. Figure 1 shows the present state of the distribution system.

It very soon became apparent that the load could be conveniently divided into two parts. The first comprised the rolling-mill loads likely to produce high peaks, *i.e.*,

(i) Three 4500-h.p. synchronous motors driving roughing stands of the hot strip mill
(ii) The 21,000-kW. rectifier installation for the finishing stands of the same mill.

This was originally to be fed by two 17,500-kVA. 66,000/11,000-V. transformers; later the supply was augmented by a third similar transformer, and the load was increased by two 7500-h.p. synchronous motor-generator sets for the cold mill. Owing to the number of synchronous motors, high values of short-circuit current were inevitable, and switchgear with a rupturing capacity of 500 MVA. had to be used; but for the use of the rectifiers mentioned, reactors would also have been needed to keep down to this figure.

The second part comprised the rest of the works load. This included the 'softer' rolling loads, such as the 3500-h.p. broadside stand of the hot strip mill and the 6500-h.p. slabbing-mill Ilgner set, which each have flywheels. As the works lighting had to be fed from this section, reasonable voltage regulation was essential. In the early stages of the work, the exact number of 11,000-V. circuit-breakers required for the second part could not be ascertained, but it seemed certain that a large number would be needed. It was decided to adopt a policy of sectioning to enable switchgear with a rupturing capacity of 250 MVA. to be used. If this had not been done, more 500-MVA. gear would have been needed. The following advantages resulted:

(i) The amount of load centred on any section of switchgear is not excessive
(ii) The reduced cost of the switchgear more than counterbalances the extra cost of dividing the system
(iii) When lower-voltage supplies are required, it is possible to use a larger number of smaller transformers and to locate them nearer the load they have to supply
(iv) The minimum size of cable is reduced
(v) If a fault occurs, the damage is restricted.

At first, this system was to be divided into two sections, each supplied by one 10,000-kVA. 66,000/11,000-V. transformer and one 8000-kW. generator. Later, when the cold mill was authorized, a third section, fed from another 10,000-kVA. transformer, was added. The sections are interconnected through reactors arranged on the 'bus-tie' principle, with an emergency link through another reactor from the bus-tie switchgear to the 500-MVA. switchgear. Provision has also been made for interconnection with the subsidiary 11,000-V. supplies.

Need for Standby Supplies

Production managers usually emphasize the need

for providing standby to ensure continuity of electrical supply to their departments, supporting their argument by quoting the cost of a shutdown. Operating engineers also ask for standby, partly because it enables equipment to be taken out of service for maintenance during working hours and partly from the sense of security it gives. Directors will either ask about the cost of standby supply, or about the probability of failure, so as to assess whether the risk of working without standby is worth taking. The latter is by far the more difficult question to answer.

No statistical information applicable to steelworks in general is available, but experience of transformer reliability at one works can be quoted. At this works, 26 transformers are installed, with high-voltage windings for 3300 V. and over; the total capacity is 84,000 kVA. The transformers are of the outdoor type, but the connections are all taken out through cable boxes, so that there are no exposed bushings. The transformers are controlled by oil circuit-breakers, which, for 3300 V. and over, are contained in metal-clad compound-filled switchgear. This installation has been operating for 16 years and, taking into account the high- and low-voltage switchgear and the connections associated with them, there has, so far, been only one failure.

Although this high degree of reliability has been obtained over a period of years with a certain set of conditions, it is not suggested that similar results may be obtained elsewhere; for instance, open bushings and on-load tap-changing equipment will increase the probability of failure, although with good design this is difficult to assess.

The need for standby supplies is influenced by the the uses of the supply; *e.g.*, it was considered to be illogical to provide any standby to a drive that was not, in itself, duplicated. The slabbing mill is driven by one Ilgner set and a single set of motors, which are in turn supplied by one cable from one section of switchgear. Two cables from two different sections of switchgear could have been provided, but to do this was considered to be strengthening only the stronger links of the chain.

The section of 11-kV. switchgear supplying the slabbing mill has been fed through a 66,000/11,000-V. transformer with on-load tap changing, and the high-voltage side of this transformer had to be connected through outdoor bushings to overhead lines; furthermore, this section of switchgear was needed to control other supplies. Here the degree of reliability was considered to be insufficient, and so standby was provided, partly by connections through reactors to another section of switchgear and partly by interconnection with the power house.

Although the slabbing mill depends for its main drive on a single point of supply, standby has been provided from other sources for lighting and cranes. This is important because, although a shutdown of the mill at holiday time might be thought to give an opportunity for obtaining possession of a section of main switchgear, the same shutdown will inevitably be utilized for major mechanical maintenance and other electrical maintenance. Such standby will also enable the electrical department to take advantage of mechanical failure on the mill to get at the switchgear and, *vice versa*, in the unlikely event of a switchgear failure, advantage can be taken of the stoppage by those responsible for mechanical maintenance.

A usual feature of hot metal rolling is that the mill spends some part of its time 'waiting for heat' at the soaking pits or reheating furnace, or there may be just not enough metal available for non-stop rolling. It is thus usually possible to make up for lost time after a mishap. In continuous processes, such as in the melting shop and blast furnaces, time lost cannot be regained. For such departments as these, standby supply has therefore been provided: *e.g.*, the melting shop has been supplied by a sectioned 11,000-V. switchboard connected to two sources of supply.

The greatest need for continuity of supply is where a stoppage can cause damage as well as loss of output during the stoppage. This applies particularly to the pumps used for furnace-cooling water. Spare pumping sets were provided, and it has been necessary to divide the switchgear into two sections, so that if one half is out of action, the other can carry on. Sometimes it is not enough to divide the switchgear into two sections, and at both Margam power house and Abbey pump house three sections have been provided, so that a reasonable percentage of the pumps can be kept in service while one section of switchgear is out of action. At these two places, arrangements have also been made whereby it is possible, by suitable switching and operation of automatic protective gear, to supply the pumps from either the Grid or the Company's generators.

Voltages Used

The following systems of supply were in operation in 1945:

33,000-V., 3-phase, 3-wire: incoming supply
11,000-V., 3-phase, 3-wire: incoming standby supply and colliery supplies
3300-V., 3-phase, 3-wire: works generation and distribution
400-V., 3-phase, 3-wire: local power and distribution
200/115-V., 3-phase, 4-wire: lighting
440-V., 2-wire: D.C. to cranes and variable-speed motors
220-V., 2-wire: D.C. to cranes and variable-speed motors.

To provide for the 1946–52 developments, this list was amended as follows:

The 66,000-*V. Supply*—The 33,000-V. mains in the district could not carry the increased load; the South Wales Power Co. found that the most convenient way of transmitting the power from their Llynfi and Upper Boat power stations was at 66,000 V., the bus-bar voltage at these stations. The 33,000-V. transmission line could be reconstructed for 66,000-V. working, and so 33,000 V. ceased to be used.

The 11,000-*V. Supply*—This voltage was used for the internal works distribution, for generation, and for motors over 4000 h.p. Interconnection with the collieries was maintained at this voltage to provide mutual standby. A higher voltage would have been unsuitable for the size of generators and motors concerned, and would have increased switchgear costs.

The 3300-*V. Supply*—This voltage was used for the works sub-distribution, for motors over 100 h.p., and for small generators.

Reference	Description	Horse-power Installed	Eff.	Kilowatts			cosϕ	tanϕ	Reactive kVA.			Kilovolt-amperes
				Installed	Diversity	After Diversity			Installed	Diversity	After Diversity	

Department..... Volts..... Designation.....

Fig. 2—Table used for assessing total works load

The 415/240-*V.* 3-*Phase* 4-*Wire Supply*—As this voltage had been adopted as a national standard, all new equipment was ordered to be suitable for this supply. The 200/115-V. system was abandoned on new work because it could not supply the large amount of mixed tungsten and high-pressure mercury-vapour lighting loads.

The 110-*V. Single-Phase Mid-Point Earthed Supply*—This supply has been used for portable lights and tools.

The 440-*V.* 2-*Wire D.C. Supply*—Practically all new variable-speed motors (other than Ward-Leonard) for cranes, mill auxiliaries, etc., were operated at this voltage so as to save copper and maintain good voltage regulation; when this decision was made, however, the great increase in the price of copper was not foreseen.

The 220-*V.* 2-*Wire D.C. Supply*—This voltage was retained for Margam melting shop, and used for transfer cars where a running-rail return had to be used.

ASSESSMENT OF THE LOAD

Assessing the load was a difficult task for two main reasons:

(i) A detailed list of all the drives was not available
(ii) There was no accurate way of determining diversity. Even where the duty cycle of a drive is known, the designer may have kept something in reserve when allocating the horsepower of the motor driving it. Furthermore, as motor sizes are standardized, the drive is probably over-motored, owing to the next size larger being used.

In spite of these difficulties, all the drives known were listed, and where there were gaps, the information was assessed using, as far as possible, data from other plants. Fortunately, considerable detail was available for the major drives, and it was only for the less important ones that some guesswork was needed. This information was accumulated in tabular form, switchboard by switchboard and voltage by voltage, until the total works load was deduced. Figure 2 shows the table used.

The figures used for diversity are such as to determine what the half-hourly demand of each item would be if it were running separately. When several items are grouped together to form one panel, an overall diversity is applied to give the overall maximum demand of the group, and thereby to check whether the feeder or transformer supplying it is large enough. If there are three pumps, with one running continuously, one cutting in and out on float control, and the third as standby, the diversity could be assumed to be about 50%, *i.e.*, one pump running continuously and the other half the time. As the pumps themselves are probably over-motored, the diversity is taken to be 45% for the kW. demand. Since the reactive kVA. is very approximately constant over the working range of the motor, the 50% figure is used. If a group of machine tools had been considered, there would have been considerable diversity for the kW., as at any given time a number of machines would not be running, and few of those that were running would be taking their maximum cut.

The reactive kVA. is, however, higher, because it is more dependent on the number of machines running than on the load of those that are working. By pursuing this method, the kW. and the reactive kVA. can be added up separately, so that the power factor, and hence the kVA., of the group can be assessed.

Errors have usually been due to the requirements of the plant not being fully known. For example, the transformers providing the 3300-V. supply at the strip mill were found to be fully loaded because standby pumps were needed to run under normal operating conditions. Further pumps and an additional transformer are therefore being installed.

As a result of this method of tabulation, the load was assessed as follows:

	kW.	Reactive kVA.	Cos ϕ	kVA.
Works load	59,000	22,500	0·93	64,500
Less generation	11,000	12,000	0·735	15,000
Demand on S.W.E.B.	48,000	10,500	0·985	48,800

During 1952 the demand on the South Wales Electricity Board has risen to 37,575 kW. (37,578 kVA.). The discrepancy between the estimated and actual demands is partly accounted for by the following:

(i) The load has not yet finished ' building up '
(ii) Some plant remains to be commissioned
(iii) The heavy bar mill at Port Talbot has ceased operation.

On the other hand, there have been some loads that were not originally allowed for, so that the initial figure will probably prove to have been an over-estimate, but only by a reasonable amount for contingencies.

Choice of High-Voltage Switchgear

Switchgear with the following rupturing capacities was needed:

11,000 V.	500 MVA.
11,000 V.	250 MVA.
3300 V.	75 MVA.
3300 V.	25 MVA.

If possible, switchgear suitable for steelworks use should incorporate the following features:

(i) Air (not air-blast) circuit-breakers capable of making and breaking both load and short-circuit currents and requiring little maintenance, even when used for arc furnaces, for motor-control duties, or for carrying continuous loads

(ii) Metal-clad construction, with either vertical or horizontal isolation and provided with the usual interlocks to ensure safety and easy maintenance

(iii) Vermin-proof and unaffected by dust, even that of a conducting nature

(iv) No oil or compound filling (except cable boxes); as a second line of defence, however, all bus-bars and other copper-work must be covered with a homogeneous layer of insulating material

(v) Reliability must have been proved under service conditions

(vi) The cost must be competitive.

Although such gear was available in America and was known to be in service in American steelplants, its purchase was judged to be an unnecessary expenditure of dollars when a wide choice of British switchgear was available. Owing to differences between the British Standard Specifications and the corresponding American requirements, a 'rate of exchange' exists between 'sterling' and 'dollar' MVA.

Air-blast switchgear was available for 11,000 V., but it was:

(i) In very short supply

(ii) Expensive, particularly for 250 MVA.

(iii) Not available in metal-clad construction.

Its use was therefore restricted to the starting, reversing, and inching of the 4500-h.p. synchronous motors driving the roughing stands of the hot strip mill. In fact, these circuit-breakers operate as contactors rather than as circuit-breakers.

For the rest of the 11,000-V. switchgear, horizontal or vertical isolating metal-clad gear with oil circuit-breakers was used. The bus-bar chambers were compound-filled, but current and voltage transformer chambers were oil-filled. The only alternatives were gear of either cubicle or cellular construction.

Truck-type 3300-V. switchgear was available, but it was very expensive and difficult to make dust- and vermin-proof. Only one such unit has been used for the control of an arc furnace, and so far it has operated satisfactorily.

Small metal-clad switchgear, incorporating oil circuit-breakers, was used at 3300 V. on the ore transporters. This type of gear has been developed for mining and is often called 'pillar' gear. It was thought that ordinary distribution switchgear would be unsuitable for the rough conditions. The ore transporters had to be fed through separate 1500-kVA. transformers to ensure that the 25-MVA. rating of the mining gear was not exceeded.

Apart from these special cases, horizontal-isolation metal-clad switchgear was used for 3300 V., but, unlike with the 11,000-V. switchgear, it was possible to get gear without 'filled' bus-bar and current-transformer chambers by covering the conductors with a layer of insulating material.

Choice of Medium-Voltage (415-V.) Switchgear

Similar considerations apply when choosing medium-voltage as when choosing high-voltage switchgear. The absence of oil is not so important, since the full quantity in any circuit-breaker is small. Suitable switchgear, of metal-clad air-insulated construction, was available, but it was considered to be too expensive for general use. Air circuit-breakers were, however, used to form part of open switchboards in motor rooms, where they had to line up with open contactor boards and D.C. switchboards.

The remainder of the 415-V. switchgear was of the air-insulated type, incorporating metal-clad oil circuit-breakers with vertical isolation.

It is often necessary to assign to switchgear a current rating that is lower than the nominal rating. The need for de-rating is not so urgent on high-voltage switchgear, where many of the circuits are less than the minimum size obtainable, as it is on low-voltage switchgear. The relevant British Standard Specifications permit:

(i) No overload capacity

(ii) Temperature rises up to 50° C. above an ambient temperature of 35° C.

If switchgear is to operate without maintenance it must run cool when carrying its normal load current continuously. For instance, the output from the 431-V. winding of an 800-kVA. transformer is 1070 amp. If a 1200-A. circuit-breaker is used, it will be quite hot when carrying the full load of the transformer, and it will be overheated if the transformer is called on to carry its permitted overloads. For this duty, the next highest standard rating, *i.e.*, 1600-A., has been chosen.

Switchgear Erection Experience

When a switchgear manufacturer has completed his drawings, he starts to build the gear, but it is not possible to design the sub-station until these drawings are available. Builders and switchgear makers have their own particular material shortages and delays, and the builder usually takes at least as long to complete the building as the manufacturer takes to construct the gear in his factory. The result is the switchgear is ready before the building, and the maker complains that the site is not ready to receive it.

Although the switchgear maker is not responsible for erecting the building, he can help its speedy completion by requiring only the simplest of foundations. For instance, it must be possible to construct a simple cable trench behind each switchboard clear of the surface needed to support the gear, and all the cable glands can project over the trench so as to avoid pockets in its sides. Some holes must be provided for holding-down bolts but even the number of these could be reduced. Switch gear manufacturers must also remember that cables have to be run to the gear after it has been erected, and that cable boxes near ground level may need an unduly deep cable trench.

Operating Experience with Switchgear

The reliability of steelworks switchgear should be beyond question, but experience with it has been

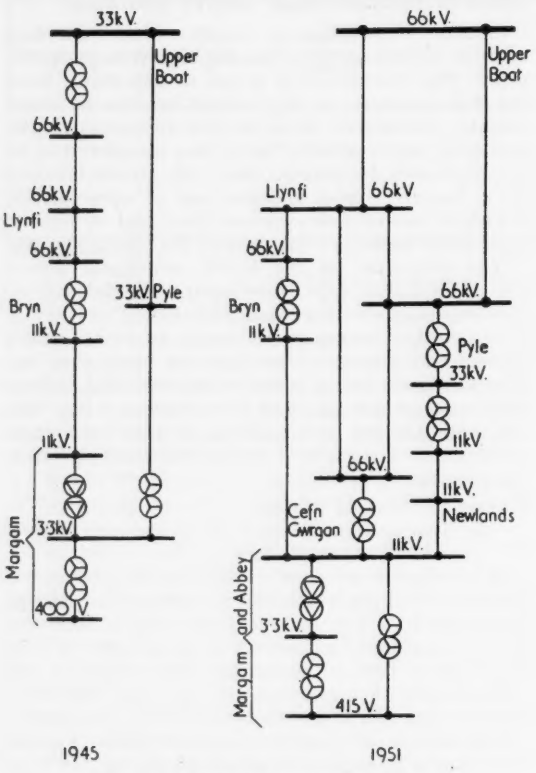


Fig. 3—Phasing of transformers

very mixed. It is difficult to explain why faults should show up in a steelworks using gear that has been produced in large quantities and has apparently given satisfactory service in other industries and on supply authorities' networks. Although the ability of circuit-breakers to interrupt short-circuit currents has been satisfactory, the types of trouble encountered with the switchgear are illustrated by the following examples:

(*a*) A weak design of mechanical interlock enabled a closed oil circuit-breaker to be pushed in, so that the isolating plugs completed the circuit to a standing alternator.

(*b*) A design of bus-bar orifice shutter incorporating twin flaps had provision for padlocking, but, if the shutters were closed in the wrong sequence, only one flap was padlocked.

(*c*) A 'ring-main' feeder isolator caught fire, as a result of a fault. There was some doubt about the ability of the isolator to be closed on a fault, but it was out of adjustment owing to an inefficient locking device, and was making poor contact. The trouble was aggravated by smoke spreading along the 'unfilled' bus-bar chamber. As well as solving these difficulties, it would be worthwhile to pay a higher price and make the isolators withdrawable, so that maintenance can be carried out with bus-bars alive.

(*d*) Circuit labels have been found fitted to removable covers.

(*e*) Switch-position indicators have been unreliable; the indicator on a switch whose contacts were touching showed it to be open.

(*f*) Mechanisms have been unreliable; a fractured link jammed a mechanism on an alternator circuit-breaker so that it would not trip.

(*g*) A serious oil leak from a current-transformer chamber was caused by a faulty locking device.

(*h*) A flashover in an oil-filled current-transformer chamber was thought to be due to some contamination of the oil, caused either by lack of care when filling the chamber or because there was no gasket to the top cover.

(*j*) A flashover in oil-immersed current transformers was due to a poor design or material of bushing.

(*k*) The wheels on circuit-breaker trucks should be large enough not to wear a rut in an ordinary concrete floor, and the general design should be such that, for all except the largest sizes, it can be manœuvred easily by one man.

(*l*) Under-voltage releases have prevented breakers from latching in. This has caused much unnecessary oil and contact maintenance on switches controlling direct-on starting squirrel-cage motors.

(*m*) Circuit-breakers controlling motors and arc furnaces need operation counters so that maintenance can be done after a predetermined number of operations.

(*n*) Poor copper joints have caused overheating on medium-voltage switchgear.

(*o*) The numbering of small wiring has sometimes been skimped, causing too much reference to schematic and connection diagrams.

(*p*) Variations in the design of two different current ratings of circuit-breakers lined up in one switchboard led to an error by an operator which caused a flashover.

(*q*) Some swarf shorted out the interlocks of two 'reversing' circuit-breakers so that both closed together and caused a short-circuit. A positive mechanical interlock seems to be the solution, but is very difficult to apply.

TRANSFORMERS

The transformers used for the distribution system are all of the ON type. The vector group references of the transformers were influenced by past history (*see* Fig. 3).

The low-voltage windings of the transformers were designed to give a voltage slightly above the nominal voltage of supply; *e.g.*, 3400 V. for a 3300-V. supply and 431 V. for a 415-V. supply. Some time after it had been decided to adopt 431 V., it was learnt that the British Electricity Authority had decided to use 433 V.

The main difficulty experienced with transformers has been that of getting paint capable of withstanding a combination of seaside and steelworks atmospheres. In general, there would be less trouble if greater care were taken with the application of the priming coats.

Table I is a summary of the characteristics of the transformers installed. All the transformers are suitable for use outdoors, and are provided with conservators and silica-gel breathers. The larger transformers are provided with two Buchholtz float devices and link-type cable boxes.

As better grades of core iron become available, it should be possible for future designs to operate with reduced losses. At present, it is doubtful whether the extra cost of buying transformers with especially low iron losses is worthwhile. The technique of using low-loss iron requires great care during manufacture, because such work on the metal as punching or shearing may upset its characteristics. Furthermore, it has yet to be proved whether the metal will main-

Table I

SCHEDULE OF DISTRIBUTION TRANSFORMERS

Continuous output, kVA.	**3500**	**1500**	**800**	**400**
High-voltage line pressure, V.	**11,000**	**11,000**	**11,000**	**3300**
Low-voltage line pressure (no-load), V.	**3400**	**3400**	**431**	**431**
Vector group reference	**12 *Dd*0**	**13 *Dz*0**	**11 *Yy*0**	**11 *Yy*0**
Core loss, W.	**9585**	**4762**	**2925**	**1640**
Copper loss, W.	**29,200**	**16,275**	**10,100**	**5843**
Reactance, %	**6·75**	**6·4**	**6**	**4·7**

tain its characteristics during many years of service. At an associated steelworks some transformers have been installed that incorporate a low-loss iron, and it is hoped that it may be possible to find out whether there is any increase in the iron loss as the transformers grow old.

RECTIFIERS

The following rectifiers were installed:

(i) A 21,000-kW. group of grid-controlled pumpless steel-tank rectifiers arranged to give 60-phase rectification. These rectifiers supply D.C. at 800 V. to the motors driving the finishing stands of the hot strip mill.

(ii) Six 1600-kW. groups of pumpless steel-tank rectifiers for the general 440-V. D.C. supply at Abbey Works. Each group is supplied by one transformer and comprises four cylinders. The anodes of the rectifiers are protected by cartridge fuses. Each group operating alone gives 12-phase rectification, but, by using extended delta connections on the high-voltage winding of the transformers, each pair of groups gives 24-phase rectification when the load is shared.

(iii) Two 200-kW. groups of glass-bulb rectifiers for the general 440-V. D.C. supply provided from Morfa sub-station to the repair shops.

(iv) Two 300-kW. groups of glass-bulb rectifiers for the 220-V. D.C. supply to the transfer cars associated with the Margam blast-furnaces.

The glass-bulb rectifiers are protected by the usual cartridge anode fuses, and each group includes an inverter, which operates to absorb any regeneration, and prevents any undue rise of voltage at no-load.

No ill-effects have been noticed from harmonics introduced by the rectifiers into the voltage wave form. Figure 4 shows some typical oscillograms.

CABLES

Paper-insulated lead-covered cables have been used throughout. Single-core cables have been used for the low-voltage connections to transformers, where the current to be carried was inconveniently large for multi-core cables, and for some D.C. mains.

Except for the transformer connections, the cables were armoured with steel wire, when this could be obtained; unfortunately, this was not always possible. As well as giving mechanical protection, the wire armouring provides a path for earth-fault currents that has a much lower impedance than either steel-tape armouring or a plain lead sheath.

The cables were finished overall with a tight braiding of either jute or cotton, depending on the materials available at the time of manufacture. Where the run is all or partly buried, the braid is impregnated with a bituminous compound; otherwise it is impregnated with fire-resisting material. This arrangement is unsatisfactory when a length of cable is buried for part of its run, and is carried in a cable tunnel for the rest of the way, where it is desirable to take precautions against fire; until an impregnation which is both fireproof and waterproof can be found, however, there seems to be no satisfactory alternative.

Where many cables follow the same route, tunnels have been constructed. No special arrangements have been made for ventilating these, and in practice, sufficient air to keep the atmosphere pure and cool is found to circulate. The use of cable tunnels has avoided the need for de-rating the cables. Had the large groups of cables been buried or pulled into nests of ducts, de-rating factors as low as 40–50% would apply, and the number of cables would have had to be doubled.

OPERATION OF GENERATORS IN MARGAM POWER HOUSE

The following scheme was devised to ensure

(i) Maximum fuel economy, by using up all surplus gas

(ii) Maximum power-factor correction

(iii) Maximum availability of generating capacity if the public supply fails.

The two principal generators are driven by mixed pressure condensing turbines. Normally, these generators run in parallel with the Grid, which governs their speed. The governors of these turbines are operated by inlet-pressure control, *i.e.*, when the

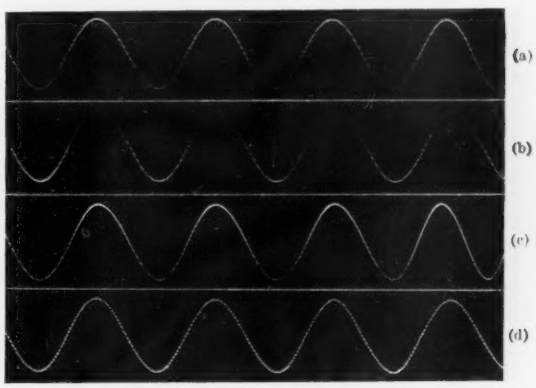


Fig. 4—Typical oscillograms of the voltage wave form: (*a*) 66-kV. phase-to-phase voltage with finishing-mill rectifiers off-load; (*b*) as (*a*), with rectifiers on-load; (c) 11-kV. (Section B) phase-to-phase voltage, with finishing-mill rectifiers off-load; (*d*) as (c) with rectifiers on-load

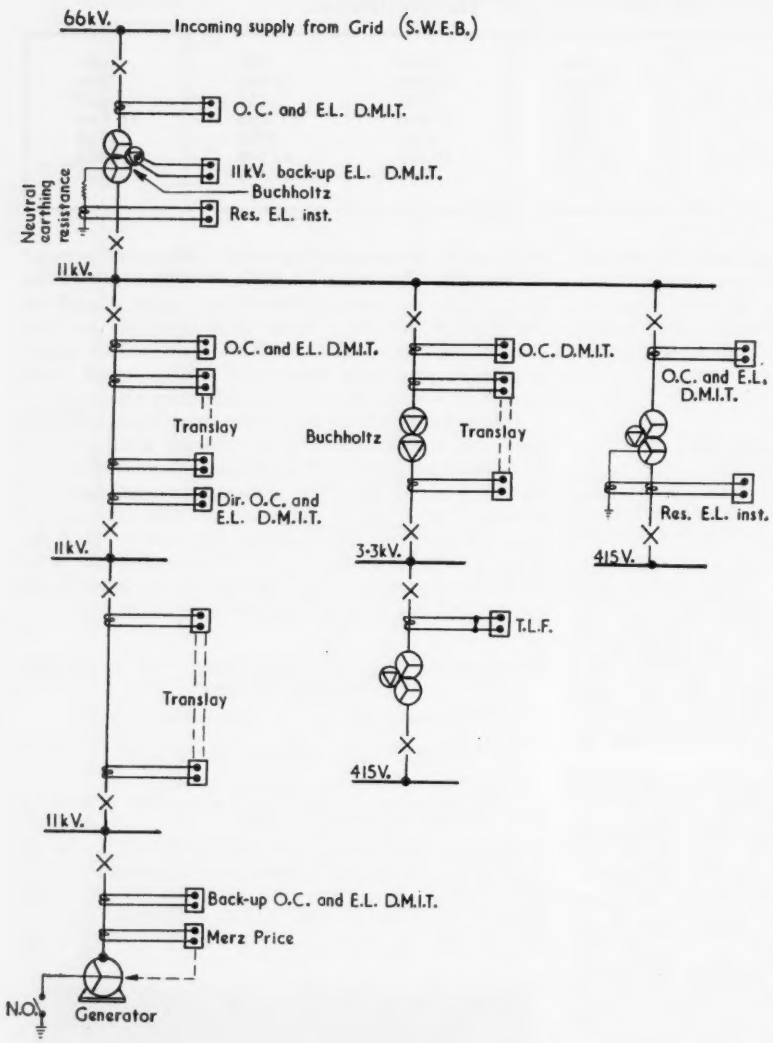


Fig. 5—Schematic diagram showing protection of 11,000-V. circuits

boiler pressure rises, the sets take more steam, and *vice versa*. In this way, kilowatts are generated in accordance with the varying amounts of excess gas (blast-furnace and coke-oven) available at the boilers.

If the speed of the sets differs from normal by more than a predetermined amount, the governors change over automatically to conventional speed-governing. Thus, if an emergency occurs and the tie with the Grid is lost, the sets continue generating. To assist this, the power house is linked to the rest of the system through circuit-breakers protected by lightly set directional over-current relays. In the event of trouble, such as a failure of the Grid, this protection operates and leaves the generators loaded, but not overloaded. Should there be insufficient gas available to maintain the steam made during an emergency, the boiler output can be boosted with oil.

To provide the maximum amount of power-factor correction, each generator is operated with its field fully excited. Voltage regulators are provided, but these are adjusted to give the regulator a setting slightly in excess of normal volts, so that it tries to increase the volts by strengthening the field until the limit is reached, *i.e.*, the maximum amount of power-factor correction is obtained. If the generator is suddenly disconnected from the Grid, there may not be enough load to hold down the volts, but these will only rise by a small amount until the setting of the regulator is reached.

PROTECTION

The arrangement of a protective system is affected by two opposing demands. On the one hand, to obtain instantaneous operation and complete discrimination under all conditions of fault will require many complicated and costly schemes of balanced protection, including bus-zone protection. On the other hand, the use of simple over-current protection will mean either unduly long time delays, if discrimination is sought on a time basis, or else the risk of unnecessary shut-downs owing to lack of selectivity. On this distribution system, a compromise has been attempted.

All the 11,000-V. circuits have almost instantaneous earth-leakage protection, except the bus-bars, which are protected on a time-graded basis; the arrangement is shown in Fig. 5.

The 11,000-V. neutral is normally earthed at the main 66,000/11,000-V. supply transformers, and, in case third harmonic currents should circulate through 'earth,' the generator neutrals are insulated. Thus, if the generators become separated from the Grid, the part of the system remaining connected to them would operate with an unearthed neutral. This possibility is dealt with in two ways. Firstly, certain potential transformers at the power house have earthed high-voltage star points and delta windings, connected to give an alarm if one phase is earthed. Secondly, circuit-breakers have been provided for earthing the generator neutrals if it seems likely that

the period of separation from the Grid will be prolonged.

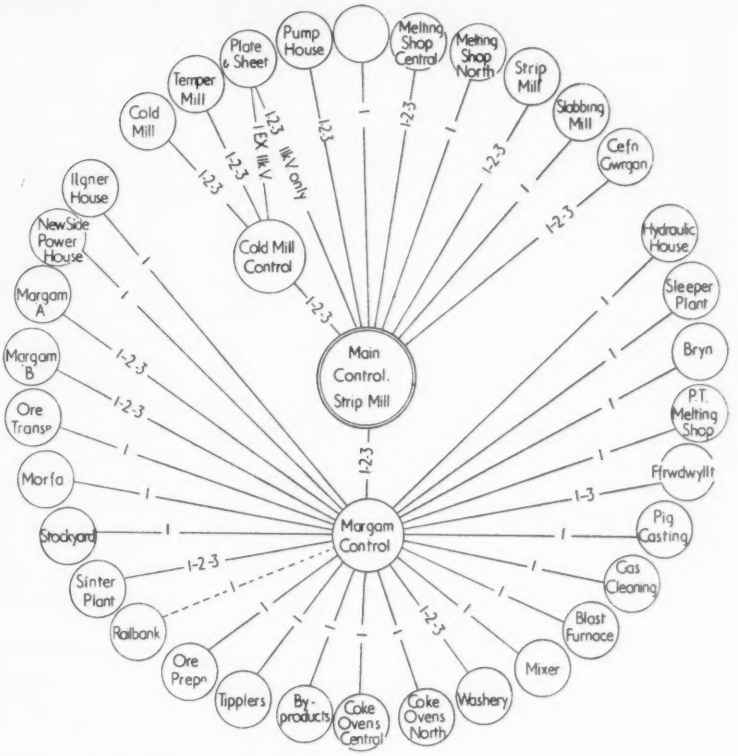
Over-current protection calls for little comment except that:

(i) For motors, separate elements have been provided to give instantaneous protection for short-circuits and thermal protection against overload.

(ii) For rectifiers, instantaneous elements have been provided for protection against backfires, in addition to definite minimum inverse-time relays, which back-up the D.C. protection.

Translay balanced-voltage protection has been provided for all 11,000-V. feeders and for the 11,000/3300-V. transformers. These transformers were protected in this way, so as to include their low-voltage windings, with unearthed neutral in the protected zone. Using balanced protection for these duties helps the time grading of the back-up protection, and guards against bus-bar faults.

The 3300-V. supplies are normally operated as separate small self-contained systems, each fed from one 3500-kVA. transformer. The neutral is not earthed, and so potential transformers are used to operate earth-leakage indicators, as described for the 11,000-V. system. Owing to the simplicity of each separate system, only over-current protection is used.



1 Instruction control of all circuits
2 Direct remote control of 11-kV. switchgear circuits
3 Future supervisory control and indication of interconnected 11-kV. circuits from main control room

Fig. 6—Diagram showing control and operation of electrical supply, generation, and distribution at Abbey, Margam, and Port Talbot Works.

Like the 3300-V. supplies, the 415-V. supplies are normally operated as separate systems, each fed by either an 800- or a 400-kVA. transformer. Restricted earth-leakage protection was used for the low-voltage windings of the 800-kVA. transformers where the back-up from the over-current protection on the high-voltage side of the transformer would have been very insensitive; otherwise, all the 415-V. protection is by over-current only. As the distribution is by cable, the sheaths provide a sufficiently low impedance path to operate the over-current trips on the sub-station feeder circuit-breakers.

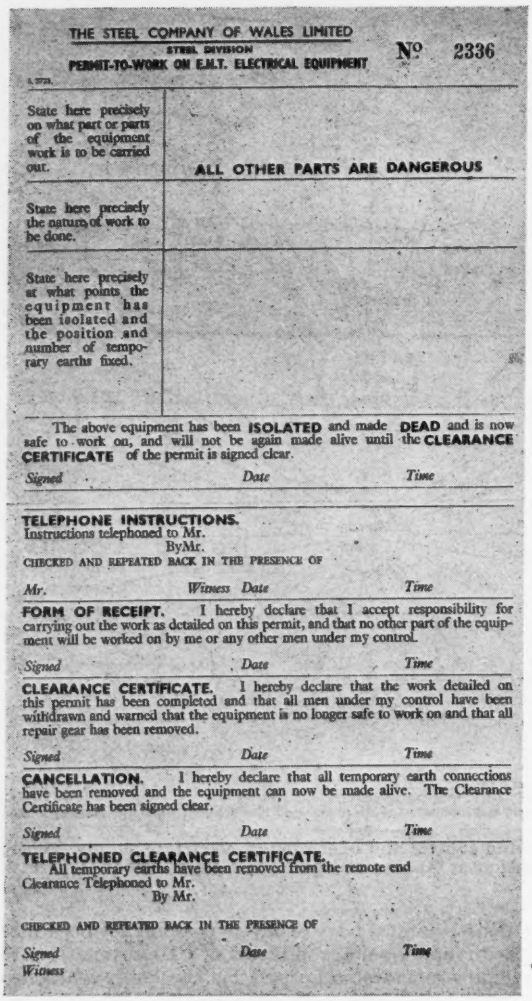
On switchgear, under-voltage protection has been provided only on high-voltage circuit-breakers controlling individual motors. As well as fulfilling its usual function of guarding the operator from harm due to his machine starting unexpectedly, the protection also helps in another way. Many of the switchboards control large groups of direct-on starting motors; if all tried to start together after an interruption, they would trip the incoming supply. To assist the maintenance of supply in times of emergency, the power house auxiliaries (*e.g.*, condenser pumps) have as far as possible not been fitted with under-voltage protection. Unfortunately, the motor-generator sets used for the boiler-fan control must have under-voltage protection. To avoid tripping out during momentary voltage reductions, under-voltage relays of the induction type, operating in conjunction with shunt trips, have been used. A difficulty associated with under-voltage releases has been to find a reliable supply for them, because potential transformers do not give enough output to allow discrimination between successive auxiliary fuses.

CONTROL AND OPERATION OF SYSTEM

Control

Centralized control is needed for the safe, efficient, and economic operation of a system such as the one that has been described. The control scheme is shown in Fig. 6.

The primary duty of a control engineer is to operate the system safely, to maintain continuity of supply throughout the works, and at the same time to operate the network economically by attention to such items as the maintenance of standard voltage and frequency, the proper loading of cables, transformers, and generators, system power factor, and maximum demand.



THE STEEL COMPANY OF WALES LIMITED
STEEL DIVISION
PERMIT-TO-WORK ON E.H.T. ELECTRICAL EQUIPMENT No. 2336

S.3723.

State here precisely on what part or parts of the equipment work is to be carried out. — ALL OTHER PARTS ARE DANGEROUS

State here precisely the nature of work to be done.

State here precisely at what points the equipment has been isolated and the position and number of temporary earths fixed.

The above equipment has been **ISOLATED** and made **DEAD** and is now safe to work on, and will not be again made alive until the **CLEARANCE CERTIFICATE** of the permit is signed clear.

Signed *Date* *Time*

TELEPHONE INSTRUCTIONS.
Instructions telephoned to Mr.
By Mr.
CHECKED AND REPEATED BACK IN THE PRESENCE OF
Mr. *Witness* *Date* *Time*

FORM OF RECEIPT. I hereby declare that I accept responsibility for carrying out the work as detailed on this permit, and that no other part of the equipment will be worked on by me or any other men under my control.

Signed *Date* *Time*

CLEARANCE CERTIFICATE. I hereby declare that the work detailed on this permit has been completed and that all men under my control have been withdrawn and warned that the equipment is no longer safe to work on and that all repair gear has been removed.

Signed *Date* *Time*

CANCELLATION. I hereby declare that all temporary earth connections have been removed and the equipment can now be made alive. The Clearance Certificate has been signed clear.

Signed *Date* *Time*

TELEPHONED CLEARANCE CERTIFICATE.
All temporary earths have been removed from the remote end
Clearance Telephoned to Mr.
By Mr.
CHECKED AND REPEATED BACK IN THE PRESENCE OF
Signed *Date* *Time*
Witness

Fig. 7—' Permit-to-Work ' card

The co-ordinating control and operation of a large interconnected system in an iron and steelworks differs in many respects from the more generally accepted type of control room. The load is a rapidly fluctuating one caused by the peaks produced by large rolling mills, arc-furnace loads, direct-on switching of motors up to 2000 h.p., simultaneous reduced-voltage starting of machines totalling 28,000 h.p., and comparatively frequent changes in works generating output occasioned by changes in fuel conditions.

In cases of emergency due to failure of supplies, rapid action must be taken to avoid interruptions to vital plant, such as water-circulating pumps for furnace cooling, power-station auxiliaries, melting-shop cranes, annealing furnaces, blast-furnaces, and coke ovens.

Owing to the limited water-storage facilities, an interruption of supply to the water-circulating pumps of 10 min. will have disastrous effects on blast-furnaces, melting shop, and coke ovens, caused by burnt-out cooling systems.

To exercise the necessary control over the starting of large drives, permissive switching is extensively used, either by remote control or by verbal instructional methods. Before this system of control was instituted, transformers and feeders sometimes tripped out because of simultaneous direct-on starting of too many large drives.

Operating experience has shown that, to make the centralized control more effective, there must be additional indicating equipment in the main control room. It has therefore been proposed to install supervisory indication equipment covering the main circuits, with provision for remote control if necessary.

Television is also being considered as an alternative to this method, whereby the control board in the sub-control room is reproduced on a screen in the main control room. This would be supplemented by direct means of communication.

All control rooms and important sub-stations are on direct-connected ' inter-com ' circuits, so that there are no delays in transmitting messages. Radio communication is also provided between the main control room and the control centre of the Area Board. Works automatic and Post Office telephones are also installed.

Rules and Regulations

To cover the control, safe operation, and maintenance of high-voltage apparatus on the system, a set of rules has been drawn up for the guidance of all persons concerned. The rules detail the duties of those concerned with the control of the system, and also define persons who may carry out certain classes of work. These are classified as ' authorized ' or ' competent,' depending on the circumstances; having satisfactorily proved their suitability, they are issued with a certificate with the necessary endorsement.

Work on all parts of the system is covered by ' Permit-to-Work ' cards (*see* Fig. 7).

PLANNED MAINTENANCE

A comprehensive system of planned maintenance is used that covers all equipment. Each sub-station is considered separately, and all plant in and supplied from it is itemized on schedules under the sub-station heading. According to the type and duty of the plant, appropriate inspections are shown against it.

For high-voltage switchgear, these are as follows:

Class of Inspection	Work Carried Out
A. Weekly	Visual inspection of all parts
B. Annual	All items completely overhauled, tested, and checked
C. Six-monthly	Check on correct operation of protective gear and control circuits (*e.g.*, Relay operated by hand to trip oil circuit-breaker; oil circuit-breaker closed and tripped by local and remote control. No Megger testing required)
D. Determined by number of operations (logged from counters in circuit)	Oil circuit-breaker only. Tank opened, oil and contacts checked, closing and tripping checked on local and remote control.

When these inspections become due, they are ex-

S.C.O.W. LTD. STEEL DIVISION. **ELECTRICIAN'S DAILY REPORT SHEET.** DATE _____ 19____

DISTRIBUTION DEPARTMENT.

PLANT LOCATION _____ UNIT INSPECTED _____

	OPERATIONS	CLEANED	CONTACTS	LUBRICATED	PROTECTIVE SETTING	INSULATION TEST	EARTHING	COVERS TIGHT	TEST OPERATION
FIXED PORTION	BUS CHAMBER								
	C.T. CHAMBER & C.T's.					PRI. TO SEC.			
	P.T. CHAMBER & P.T.				H.V. FUSES L.V. FUSES	PRI. TO SEC.			
	CABLE ENTRY								
	AUX. SWITCHES & WIRING					SEE " SMALL WIRING "			
MOVING PORTION	CONTACTOR AND CLOSING SOLENOID				SOLENOID FUSES	TO EARTH			
	TRIP COIL				FUSES	TO EARTH			
	BUSHINGS					R–E R–Y Y–E Y–B B–E B–R			
	MECHANISM								
	CIRCUIT BREAKER					SEE " BUSHINGS "			
	AUX. SWITCHES & WIRING					ALL IN TEST TO EARTH			
METERING	SINGLE PHASE				POT FUSES				
	THREE PHASE				POT FUSES				
	INDICATING INSTRUMENTS				FUSES				
CONTROL BOARD	SMALL WIRING					ALL IN TEST TO EARTH			
	CONTROL SWITCH								
	AMMETER SWITCH								
	FUSES				CONTINUITY RATINGS				
	RESISTORS								
	SYNCHRONISING SOCKETS								
	INDICATING LAMPS								
CABLING	PILOT				SEE " FUSES "				
	MAIN				SEE " PROTECTION "	R–E R–Y Y–E Y–B B–E B–R			
OTHER PARTS									

OIL	C.T. CHAMBER & C.T's.	P.T. CHAMBER & P.T.	CIRCUIT BREAKER
	SEE TEST SHEET NO.	SEE TEST SHEET NO.	SEE TEST SHEET NO.
PROTECTION	FOR _____ SEE TEST SHEET NO.	FOR _____ SEE TEST SHEET NO.	FOR _____ SEE TEST SHEET NO.

MECHANICAL OPERATION	MECHANICAL INTERLOCKS	TRIPPING	CLOSING	No. OF TEST OPERATIONS

ELECTRICIAN'S REMARKS _____

SIGNED _____ *Electrician.*

FOREMAN'S REMARKS _____

SIGNED _____

S. 2917 H. & S. Ltd.

Fig. 8—Electrician's Daily Report Sheet

RONEODEX VISIBLE RECORDS. RONEO LTD., 17, SOUTHAMPTON ROW. W.C.1.

S.C.W. LTD. STEEL DIVISION — 2m 11-51 RONEODEX CARD No. SW.Y0468

ELECT. ENG. DISTRIBUTION DEPT. — SWITCHGEAR RECORD — S 2967

FIXED PORTION

MAKER		AMPS	VOLTS	POSITION
TYPE	RATED			INCOMING
	SYSTEM			OUTGOING

FILLING	BUSBARS	CABLE BOX	C.T. CHAMBER	P.T. CHAMBER

V.T.

SERIAL No.	RATIO	VA	CLASS	DUTY	FUSES	PRI	TER'	SEC

C.T. SERIAL Nos.	RATIO	V.A	CLASS	TYPE	DUTY
R					
Y					
B					
N					

MOVING PORTION

TYPE		AMPS	VOLTS	BREAKING CAPACITY			
	RATED			MVA	Sym KA	AsymKA	Peak KA
SERIAL No.	SYSTEM						

DIAGRAMS / DRAWINGS

CLOSING — Oil Grade & Capacity

TRIPPING

CONTACT ASS.

BUSHINGS

PROTECTION

PROTECTIVE SYSTEM	MAKER	TYPE	SERIAL No.	RANGE TIME	RANGE CURRENT VOLTAGE	COMP. RESTR.	DIAGRAMS / DRAWINGS

METERING

	TYPE	MAKER	SERIAL No.	SHUNTS	SERIES RES.	C.T.s	P.T.s
SINGLE PHASE 'A'							
SINGLE PHASE 'C'							
THREE PHASE							

	TYPE	MAKER	SERIAL No.	SHUNTS	SERIES RES.	C.T.s	P.T.s
AMMETER							
VOLTMETER							
POWER FACTOR							

ITEM Nos.	CIRCUIT	DEPT.	LOCATION

Fig. 9—Technical data record card for switchgear

tracted from the schedules and transferred to weekly instructional sheets which are issued to the foreman in charge of the work. When the work is being carried out, a special report form, one of which has been produced for each type of equipment, is filled in by the electrician as the job progresses, and is submitted after completion for the foreman's approval and signature. This is checked by the engineer before it is passed on to the maintenance records clerk, who transfers the necessary information from the electrician's report sheet to the history card of the item concerned. The schedules are then marked off to signify whether or not the inspection has been satisfactorily completed; if it has not, outstanding work is entered on a ' follow-up ' card, which is re-submitted to the foreman at appropriate intervals until the job is completed. A typical report sheet for switchgear is shown in Fig. 8. This has been developed to help the electrician in every way when reporting the work carried out, and the success of the system depends on its intelligent completion. Similar sheets are available for transformers, rectifiers, protective gear, oil, etc.

Filed with each history card is a technical data card, which gives manufacturer's references and performance figures (*see* Fig. 9). These two cards form a complete record of the particular plant.

This system, although not finally complete, has already proved its worth in all directions and at present embraces items of equipment involving about 40,000 annual inspections.

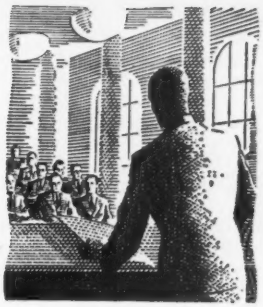
Acknowledgments

The authors wish to thank The Steel Company of Wales Ltd., and McLellan and Partners for permission to publish this paper.

References

1. *Power Works Eng.*, 1952, vol. 47, pp. 321–330
2. *Elect. Rev.*, 1951, vol. 149, pp. 823–829 and 875–887
3. *Elect. Times*, 1951, vol. 120, pp. 145–152
4. *Iron Coal Trades Rev., Special Issue*, 1951, pp. 57–75

DISCUSSION ON PAPERS



DISCUSSION AT MEETINGS · WRITTEN CONTRIBUTIONS

The Corrosion of Steel Under Phosphate Coatings and Protective Finishes

A Meeting organized by The Iron and Steel Institute in conjunction with the British Iron and Steel Research Association was held at the Offices of the Institute, 4 Grosvenor Gardens, London, S.W.1, on Tuesday, 28th October, 1952, at 2.0 p.m. Four papers on "The Corrosion of Steel Under Phosphate Coatings and Protective Finishes" were presented and discussed. Mr. H. T. SHIRLEY, Chairman of the Corrosion Committee of B.I.S.R.A., was in the Chair.

Joint Discussion on the Papers—

PHOSPHATE COATINGS AS A BASIS FOR PAINTING STEEL*

By the Phosphate Coatings (Drafting) Panel of the British Standards Institution

CORROSION BY RETAINED TREATMENT CHEMICALS ON PHOSPHATED STEEL SURFACES†

By S. G. Clarke and E. E. Longhurst

TENTATIVE ANALYTICAL TESTS FOR PHOSPHATE COATINGS ON STEEL‡

By R. St. J. Preston, R. H. Settle, and J. B. L. Worthington

The **Chairman** (Mr. H. T. Shirley) opened the Meeting, after which the authors presented their papers.

Mr. **R. J. Brown** (Morris Motors, Ltd.): The paper by Clarke and Longhurst appears to imply that certain of the proprietary phosphate processes should be avoided, even though they are regularly used with success in practice. Are the authors quite satisfied that the washing water used was not a contributory contaminant, although accelerators are shown to be the primary cause of localized corrosion? It is unfortunate that a painted plain steel reference sample was not included in the tests, unless the authors were satisfied that the tap water used for washing had an extremely low content of soluble salts.

The plain types of treatment bath, which gave reasonable results in their tests, would be uneconomic in practice for many assemblies, owing to the length of processing time. Although the results with these baths show no practical difference between washed and unwashed specimens, I suggest that a more precise test, using unwashed and efficiently washed specimens, would show at least small differences in corrosion resistance.

I agree that the washing applied to the specimens was probably far more efficient than that found in many works undertaking phosphate treatments; however, I understand it to be purely a dip wash with very little agitation —presumably a swirl round—whereas many phosphate treatments embody a very efficient rinse with sprays.

In regard to retained salts on motor car bodies, ring blistering of body finishes has been known for some years; it is due to water spots dropping on the clean body surface from overhead condensation points before painting. It was believed that continuous processing equipment, which would not only automatically clean the body but also phosphate-treat and prime the surface, would solve all such troubles; also that it would eliminate service complaints of corrosion of interior surfaces and corrosion spread beneath the paint film where local damage occurred.

* *J. Iron Steel Inst.*, 1952, vol. 170, Jan., pp. 10–15.
† *Ibid.*, pp. 15–18.
‡ *Ibid.*, pp. 19–20.

After several months' operation of this plant, reports were received of local corrosion trails* (' snail trails '), consisting of a line of fine blisters at the interface of the phosphate coating and the primer paint. Stripping of the paint revealed that these were associated with minute accumulations of rust, an analysis of the rust deposit showing the presence of both calcium and chlorides.

In the continuous processing plant, the car bodies are supported on a spit and are rotated during processing, giving adequate cleaning, uniform phosphating, and a thorough coating with a primer paint. Both exterior and interior surfaces of the body are adequately protected, the compact, finely crystalline phosphate film produced promoting excellent adherence of the paint film and protection against the spread of corrosion beneath the paint film if it is damaged in service.

The snail trails were due to local soluble contaminants on the body surface, and a survey of the processing plant showed that incrustations of soluble salts could be formed in the overhead structure and redissolved under certain conditions, subsequently dripping on to the surfaces of the bodies being processed. This was eliminated by filling in the upper part of the structure, but the continued presence of chlorides, in particular, was unsatisfactory. The only sources of chlorine compounds in the processing plant were the killed spirits used in the leading operation during body assembly, and one of the processing solutions used in the plant itself. The proportion of chlorine resulting from retained killed spirits on the body surfaces was extremely small and was discounted, and re-formulation of the processing solution was essential. This greatly reduced, but did not entirely eliminate, the corrosion trails. The corrosion occurred only on the plain body surface, and not at overlapping joints, as might be expected from Clarke and Longhurst's paper.

In spite of the proximity of the processing baths, the contamination of the washes by soluble salts carried over from the phosphating bath was negligible. The water supply had been suspect quite early in the investigations; the total hardness was 40 parts per 100,000. Laboratory tests showed that treated water such as boiler condensate or demineralized water would largely overcome the trouble, but this was not possible on the grounds of cost.

As the soluble salts in the rinses could not be completely eliminated, it was considered necessary to prevent localized evaporation of the water contained on the body surface, and sprinklers were installed between the various processing baths to ensure that the surfaces were wet throughout the operations. This helped, and the only stage at which preferential drying occurred was after the chromic rinse. Temporarily omitting this gave no further improvement, and in any case the chromic rinse prevented corrosion from spreading.

With success in sight, it was decided to seek an independent opinion, and C.R.L. were approached. They suggested that operation of the chromic rinse without heating would reduce the tendency for the body surface to dry off before reaching the force-drying stage. This gave a further slight improvement, but did not eliminate the more persistent trails which always occurred at the same locations and resulted from spillage of fluid and progressive evaporation as the body rotated. Mr. Preston provided the ultimate solution by suggesting that prevention of rotation between the chromic rinse and the force-dry would permit uniform drying over the entire body surface without the formation of trails of soluble salts.

Mr. **R. F. Drysdale** (Walterisation Co., Ltd.): Some time ago we carried out an investigation on the effect of rinsing on joints. One essential difference between our investigation and that of Clarke and Longhurst was that our weight of phosphate coating was considerably less because we felt that it was essential to consider lightweight phosphate coatings, since they are almost universally used under paint films.

Four phosphating solutions, two accelerated and two non-accelerated, were tried. The test piece was jointed vertically down the centre with the close type of joint referred to by Clarke and Longhurst, *i.e.*, the two pieces of steel were put together and squeezed in a vice.

The samples treated with each solution were separated into four groups. Those in the first group were dried without rinsing, those in the second were washed with water, the third group were washed with a dilute solution of chromic acid, and the fourth with a dilute solution of soluble chromate. After drying, all samples were given a one-dip coat of paint. All specimens were then exposed to the salt-spray test detailed under American Specification 57-0-2*c*. This test, in our experience, produces more rapid results than the normal modifications of the salt-spray test.

With the accelerated phosphating solutions our findings were very similar to those of Clarke and Longhurst; namely, that corrosion appeared in the joints of the unwashed samples very quickly indeed.

With the unaccelerated phosphating solutions, the corrosion in the joints appeared first on the samples washed with the dilute solution of chromic acid; secondly (and a very short time after the others) with the samples washed with the dilute solution of soluble chromate; thirdly, with the samples washed with water; and lastly, on the samples that had not been washed at all.

The rapid breakdown of the samples washed with chromic acid and the soluble chromate was possibly due to concentration of the rinsing solution during drying to such a degree that it became harmful. In a second series of tests, restricted to the two unaccelerated phosphating solutions, the samples were prepared in exactly the same way, but the one edge was belled slightly, and either after treatment with the unwashed samples or after washing, each joint was blown out as well as possible with a jet of air at 40 lb. pressure. Dip-coat painting and the salt-spray test were repeated. As a result, the gap between the washed samples in the two chromate solutions narrowed very appreciably and the gap between the washed and the unwashed samples also narrowed, but the unwashed samples in this particular case were still the most corrosion-resistant as regards the joints.

In a third series, also restricted to the unaccelerated solutions, the samples were divided into three groups. Those in the first group were not washed, those in the second were washed in water, and those in the third were washed in water and then in a 0·04% molar solution of phosphoric acid. All the samples were dried and coated with a one-dip coat of paint. The corrosion tests were repeated. The samples that were washed with water only corroded first. The samples washed with water and with a 0·04% molar phosphoric acid rinse and the unwashed samples failed at about the same time.

It was concluded that on such joints there are two factors: (1) possible corrosion from retained phosphate in chemicals; (2) these joints, when placed in a phosphating solution, have inside them a thin film of liquid, and this, since it is not circulating at all rapidly, becomes very quickly exhausted. Thus, very little phosphate coating is formed inside the joint itself and, after water-washing, the surface, which has been merely etched, corrodes rapidly. With no washing, or after rinsing in a dilute solution of phosphoric acid, this etched surface

* *See also J. Iron Steel Inst.*, 1952, vol. 171, May, p. 58.

reacts with the trapped liquid and a protective iron phosphate coating is formed *in situ*.

Therefore, it is felt that under certain specialized circumstances a water rinse may be deleterious, although I have no evidence that it can be deleterious with a massive phosphate coating.

Mr. **A. Nicholson** (The Pyrene Co., Ltd.): Although there is much evidence to suggest that with unaccelerated processes rinsing is unnecessary, I believe that this is not advisable when the parts are to be subsequently painted, because of the risk of osmotic blistering of the paint. On a properly phosphated steel surface such blistering need not lead to rapid spread of corrosion or degradation of the paint, but it will be unsightly and will frequently be objected to on aesthetic grounds alone.

I should like to consider whether soluble residues can be the only explanation of failure at seams, discounting purely practical causes such as incomplete drying of the seam (a common source of trouble) or the vulnerability of the paint film at the gap of the seam.

I agree with a great deal of what Mr. Drysdale said. Many seam failures are due to imperfectly formed phosphate coatings. The fact that the processing solution can be exhausted of phosphate inside the seam can be one cause of trouble. There are others.

In normal circumstances, the accelerated process forms a complete coating much more quickly than does an unaccelerated one. Within a seam, however, this degree of acceleration can be outweighed by several advantages in favour of the unaccelerated process. The unaccelerated process is usually stronger in terms of pointage, and that pointage is due entirely to active, or coat-forming, phosphate. The unaccelerated process, consequently, has a much greater acidity and reserve of activity; in the longer processing time available these properties exert their maximum effect. Although the pickling action is slow it is more thorough; oil and other surface films or deposits are more effectively displaced.

The unaccelerated processes invariably work at a much higher temperature than the others. This is of great advantage, firstly in penetration of the seam by the solution, and secondly, in the displacement of oil or dirt.

These considerations indicate that, in the particular conditions applying inside a seam, the normally accelerated process can easily fail to give as good a coating as an unaccelerated process, unless special precautions are taken. Most people with experience of phosphate coatings know that an imperfectly formed coating can be worse than no coating at all. A relationship between corrosive failure in the vicinity of the seam and incompleteness of coating inside the seam has been frequently observed. With tight seams all the conditions are present to encourage incomplete coatings.

In practice, however, before any considerations of processing arise, the most difficult problem of all has to be overcome. The seams must be cleaned effectively. Depending on the tightness of the seam, it requires little residual oil to prevent entirely any penetration by the processing solution. Clarke and Longhurst state in their paper that on deliberately oiled specimens an area was left unprocessed and there was some rusting. Could they give some more detailed information on the nature and degree of this rusting ?

In choosing a process, production considerations such as plant expenditure, heat consumption, the floor space which slower processes require, and quantity production, have to be taken into account, and accelerated processes thereby become essential. If any seam problem then exists, conditions can usually be adjusted so that an accelerated process overcomes it. Methods of curing the trouble call for consideration of the nature of the seam, followed by modification of the processing sequence and conditions or the solution composition and properties. For example, in one case, seam corrosion was cured not by eliminating the accelerator but by increasing its concentration. In the time available a complete coating of very low weight was formed inside the seam, whereas none had been formed before.

It is often advantageous to add a small amount of phosphoric acid to the final chromic acid rinse. This may be similar in effect to a zinc phosphate rinse, the subject of a German patent mentioned by the authors. In both cases the improvement may be related to the mechanism of seam corrosion that I have described, since any acid phosphate left behind in an incompletely coated seam will be converted to a phosphate coating during subsequent drying-off.

I should be interested in any comments Dr. Longhurst can make on the approach I have outlined. For example, at what pointages did he run his unaccelerated solutions, and at what temperatures ? The edges of the folds were filed off to inspect the coating inside the seam. Was there any relation between the extent of phosphate coating and degree of rusting ? Possibly no reliable assessment could be made in that way. Lastly, if the accelerator was nitrate, was any nitrate found by analysis in the seams that failed ?

Mr. **W. E. Cattley** (Walterisation Co., Ltd.): Table I of the paper by the Phosphate Coatings (Drafting) Panel gives for the iron phosphate process an immersion time of 15 min. and a coating weight of 1·31 g./sq. ft., whereas Clarke and Longhurst state that a phosphating time of 40 min. produced only a thin and uneven coating.

I immersed a steel plate in an iron phosphate solution for 35 min.; the coating was complete and was obviously quite heavy. I wonder, therefore, whether the 40-min. immersion for the thin coating is correct.

In their suggested performances tests, Clarke and Longhurst exposed their samples, suspended in air, in a vessel at room temperature, and waited for a week for signs of rust. This test might be of much interest to many users if—perhaps by having the water a little warmer—the time could be reduced from one week to 24 hr. Have the authors done any such work with a view to giving users a very interesting test ?

Mr. **E. I. Brimelow** (D.S.I.R. Building Research Station): There may be a danger in assessing phosphate coatings by accelerated corrosion tests, particularly to determine the most useful concentration of chromic acid in the rinsing solution. The percentage of chromic acid required to give good results appears to vary according to the type of phosphating process used and the method of accelerated test applied. From the results so far obtained by field tests and accelerated tests, it is suggested that 0·1–0·5% of chromic acid in the rinsing solution might be a more useful optimum range than 0·1–0·2%, as given in Clarke and Longhurst's paper.

AUTHORS' REPLIES

Dr. **J. C. Hudson** (British Iron and Steel Research Association): In reply to Mr. Cattley's question about the weight of phosphate coatings applied from iron phosphate baths, I can confirm that there is no doubt about the duration of treatment given for process *P* in Table I of the paper by the Phosphate Coatings (Drafting) Panel, as the specimens were prepared in the presence of two of my colleagues, who recorded the time, 15 min., on the spot.

The constructive remarks of Mr. Brown, Mr. Drysdale, and Mr. Nicholson, based on their practical experience of phosphating processes in industry, are valuable contri-

butions to our knowledge of the subject. I agree with Mr. Brimelow that it would be unwise to fix any hard-and-fast limit for the concentration of chromic acid rinses on the basis of laboratory tests alone. As stated in the paper, the optimum concentration may differ for different processes.

Mr. **R. St. J. Preston** (Chemical Research Laboratory, Teddington) wrote in reply: The method of preparation of the hydroquinone reagent, which was omitted from the original paper, is as follows: A 0·5% solution is made by dissolving 5 g. of hydroquinone in distilled water in a litre flask; 20 ml. of NH_2SO_4 are added and the whole is made up to 1000 ml.

I should like to thank Mr. Brown for his kind remarks about my modest contribution towards the solution of the snail-trail problem. The task involved very little work on our part, as the extensive investigations undertaken by him and Mr. Nicholson, and their staffs, had already shown the main causes of the plants' difficulties. I should like also to mention Col. Faulkner of the company responsible for the process. His explanations and interpretations of the work that had been carried out were most helpful to me in making the decision to which Mr. Brown referred.

A form of humidity test (hygroscopicity test) was included in our paper. We now have a little more information about the control of humidity. Whereas, in theory, a space is saturated with vapour when the vapour is in equilibrium with its liquid in a closed space, in practice the degree of saturation under such conditions may vary widely from 100% relative humidity. For example, a large vessel of about 10 cu. ft. capacity (a thermostat bath), containing water to a level of 3–4 in., showed relative humidities ranging from about 80 to 95% over 24 hr. With a closed beaker, containing water, in a thermostat, the time taken to reach saturation may be as long as 2 days. The hygroscopicity test therefore requires some adjustment in detailed operation, if it is to be satisfactory and reproducible.

With regard to the tests suggested in our paper, we found it very difficult, starting *ab initio*, to decide what simple tests would be suitable for standardization. Although those given may be able to show badly-made coatings, they cannot give a reliable comparison between well-made coatings of different types. For this purpose a simple solution would be offered by a laboratory corrosion test. Such a test was carried out on coatings without any paint or oil protective layer, but it was not possible to compare the results with outdoor exposure tests of painted specimens and to propose the test for standardization. In the original paper on the beaker test,* the results of outdoor tests on unpainted specimens (Table IV of the paper) show that a very thick coating (over 4 g./sq. ft.) has a high intrinsic resistance to corrosion. Moreover, the correlation coefficient between laboratory test and outdoor exposure test was 1·0, based on gains in weight, and 0·8 based on (calculated) losses of steel. No conclusion can be drawn about the behaviour of similar coatings had paint been applied.

I should like to comment on the tests on the effect of joints and laps, on rinsed and unrinsed phosphated coatings. The work-hardening due to bending and flattening the specimens should influence the corrosion rate at the worked areas. It is understood, in fact, that corrosion tends to occur preferentially at such places. Might this not cast some doubt on the conclusion? Whilst it may be argued, in theory, that a phosphating process starts like a corrosion reaction and therefore the phosphate coating should build up at the work-hardened areas, the intrinsic corrosion liability of work-hardened steel may also remain, even after phosphating; or the accelerator may tend to collect at the anodic areas. It would be interesting to repeat some of the experiments after relieving the local stresses by heat-treatment.

All the tests used a salt spray. This would not appear to be the best method of detecting the presence of residues that are believed to be causing corrosion. A plain humidity test would seem to be preferable.

Dr. **S. G. Clarke** and Dr. **E. E. Longhurst** (Armament Research Establishment, Woolwich) wrote in reply: The snail-trails to which Mr. Brown referred may be peculiar to work treated by the particular continuous process that he described. This type of defect does not appear to have occurred on work phosphated and washed by complete-immersion methods, as used widely in industry and exclusively in our work. Although spray rinsing is generally believed to be efficient under carefully designed conditions, Mr. Brown states that the snail-trails were due, at least in part, to soluble chloride residues on the surface, originating from one of the processing solutions. These residues were not completely removed by the spray rinsing, and to avoid them the processing solution had to be reformulated. This further emphasizes the need for great care in the use of accelerated phosphating solutions that contain corrosion-stimulating materials.

The fact that no untoward defects occurred in our tests on panels treated by non-accelerated processes, washed, dried, and painted, appears to indicate that the washing water used—boiled London supply water—introduced no undesirable contaminants. We do not believe that the inclusion of bare steel panels would have given much more relevant information.

With each non-accelerated phosphate process used, slightly better results were obtained on panels that were washed after phosphating. This does not agree with Mr. Drysdale's results. However, the difference may, at least partly, be connected with the fact that Mr. Drysdale used a salt-spray test. This approach may be expected to differentiate more between the protection within the crevices themselves than in the case of our approach, using humidity testing only. A humidity test seemed to be the surest way of revealing the effect of any corrosive left in processing, without introducing any other active material in the test itself.

We agree that residual phosphoric acid on steel may inhibit the appearance of rust under certain conditions. However, phosphoric acid does not react very quickly with the steel surface to produce a neutral condition free from soluble material and, as pointed out by Mr. Nicholson, soluble residues beneath a paint film can cause blistering by osmotic effects. Moreover, even when the acid has reacted with the steel, the crust of insoluble phosphates formed can interfere with the adhesion of the paint. Results of processes II and III also indicate that appreciable residues of non-accelerated phosphating solutions left in fully phosphated steel may react with the coating, making it less protective, as panels treated by these processes and not subsequently washed had a greater tendency to rust.

In regard to the completeness of phosphating within and around the crevices, Mr. Nicholson was not able to add much to what was said in our paper. As would be expected, there was little of either phosphating or rusting inside a really tight crevice. In other cases much depended on the geometry of the overlapping parts in permitting entry and exit of liquid, and on plugging by paint.

* R. St. J. Preston, *J. Iron Steel Inst.*, 1948, vol. 160, pp. 286–294.

In reply to Mr. Cattley, it should certainly be possible to use a more rapid form of humidity test, but it was not desired to over-emphasize this aspect since the test was visualized more for occasional than for regular use, *e.g.*, as an initial confirmation of the suitability of a set of working conditions or the satisfactory treatment of a particular class of article. The coatings produced by process I were admittedly thinner than usual, but the proprietary firm agreed that they were suitable for their purpose.

Discussion on the Paper—

SECOND REPORT OF THE METHODS OF TESTING (CORROSION) SUB-COMMITTEE*

Dr. **J. C. Hudson,** Chairman of the Sub-Committee, introduced the paper.

The **Chairman** (Mr. H. T. Shirley): There is one point that might be developed during the discussion, in relation to statistical correlation. In view of the general variability relating to an individual process, it is obviously of no use with a limited number of tests to try to obtain a strictly reproducible order of merit if the statistical spread is greater than the difference between the processes.

I wonder whether a more useful attitude might be taken to these tests by grouping them into families. If so, one would have to decide where the practical division comes and where it is really significant. If the tests were grouped into a limited number of such families, I think there would be much less trouble with the attempt to get some sort of real correlation.

Mr. **R. F. Drysdale** (Walterisation Co., Ltd.): This Report, and the work of the Sub-Committee, is of very great value to the corrosion research worker and to industry as a whole, and I suggest that its findings should be publicized as widely as possible by the publication of a concise, authoritative article on the question of accelerated testing and its correlation with service life.

It is generally conceded that, except in areas very close to the sea, sulphur pollution is a more potent factor in bringing about corrosion than is chloride contamination. Yet almost universal reliance is placed solely on some sort of salt-spray test as a means of accelerating corrosion. The C.R.L. sulphur dioxide test is a very soundly conceived and logical method of testing for industrial atmospheres, and it will therefore be of inestimable value in the future. Every possible means should be taken to ensure that information on this and other tests, and an understanding of them, is available to the user in industry. The test is already included in B.S.1391, but it is given there more or less as an alternative method of testing.

In regard to the C.R.L. tests, I note that there were considerable discrepancies between some of the results obtained by individual laboratories. Is the fact that there were variations in the results obtained with different finishes to be attributed to a lack of reproducibility, or to the regrettable lack of experience of the method of testing before the project was started, or is it possible that there was a slight variation in the width and depth of the scratches in the test panels supplied to individual laboratories? In other words, was the deliberate damage inflicted to these specimens in sets, or was the order in which the damage was inflicted upon the panels completely indiscriminate?

I believe that the design of the C.R.L. test apparatus has been modified since the inception of the test. Has that modification taken place since the tests discussed in the report took place, or were the tests made with the modified apparatus? It would be interesting to know whether the modification, which I believe was to the cooling coil, has any effect in improving the reproducibility.

The **Chairman**: I hope that it will be possible before long to have some such report as Mr. Drysdale has mentioned, which can be read by the man who is in a hurry and who certainly does not want to follow all the statistical details. Dr. Hudson may wish to defer this until the completion of longer-term tests, but I certainly think that we must ultimately have it.

Mr. **E. I. Brimelow** (D.S.I.R., Building Research Station): It is interesting to note that good reproducibility, in regard to order of merit, has been obtained in various laboratories using the C.R.L. and A.R.E. methods of test. From the results given in Table III for protective schemes *C* and *D*, there appears to be some difference between the laboratories in assessing the degree of failure for specimens with aluminium sprayed coatings, with and without a coat of paint. Is it intended to make further tests on these protective schemes? Moreover, the results for bare steel control specimens shown in Table VI, in which losses in weight obtained in various laboratories ranged from 2·36 to 4·94 g. (C.R.L. Test) and from 1·51 to 4·65 g. (A.R.E. Test), suggest that there is room for improvement to ensure standardization of the test conditions.

The ability of the two methods of testing to produce the same order of merit is not easily deduced from the results given in Table III. For example, the results of the C.R.L. tests indicate that the unpainted lead- and zinc-coated schemes (*F* and *J*) were inferior to the painted lead- and zinc-coated schemes (*G* and *K*), and that there was little to choose between the lead- and zinc-coated schemes; the results of the A.R.E. tests, however, indicate that a coating of paint had little effect on the final order of merit but that, under the conditions of this test, zinc-coated schemes were superior to lead-coated schemes. It has been suggested in the Report that some of the differences may be accounted for by porosity in the electrodeposited lead coatings. In addition, one might expect that the high rate of permeability of the chloride ion through the paint film in the A.R.E. test may result in more rapid electrochemical attack on the steel at the discontinuities in the lead coating and consequently more rapid failure of this protective scheme than would occur in the C.R.L. test.

A comparison of the results of the laboratory tests (Table III) with the results of field tests based on lives

* *J. Iron Steel Inst.*, 1952, vol. 171, July, pp. 255–272.

to failure (Table XI) emphasizes the need for caution when using the former results to forecast the latter. These investigations, however, have indicated particular fields of usefulness for both the A.R.E. and the C.R.L. tests.

The following tentative conclusions concerning the relative merits of the protective schemes for mild steel may be drawn from the results of the field tests for 1 yr., given in Tables VIII and XI:

(i) A sprayed coating of aluminium, 3 mils thick, with and without a coat of paint, gave the best protection. A stoved coat of priming paint to specification C.S.2249, in addition to the coating of aluminium, did not improve protection, and a similar result was obtained after a 5-yr. field test at Birmingham (Table XX). It should be noted that both the C.R.L. and A.R.E. tests gave results that were not so favourable to aluminium-coated steel.

(ii) Next in order of merit after the aluminium sprayed coatings are the electrodeposited lead, 1 mil thick and painted, and the electrodeposited zinc, 0·1 mil thick, phosphated and painted schemes. Unlike the results for aluminium sprayed coatings, a coating of paint has considerably improved the protection afforded by the other metallic coatings. This effect was most marked in the case of electrodeposited lead, and a similar result was obtained after a 5-yr. field test at Birmingham (Table XX). Both the C.R.L. and A.R.E. tests favoured the scheme consisting of an electrodeposited coating of zinc, phosphated and painted, rather than that with an electrodeposited coating of lead and painted.

(iii) A protective scheme consisting of phosphating and painting was better after 1 yr. than schemes 1 mil electrodeposited lead (bare) or 0·1 mil electrodeposited tin (bare), but was not as good as these schemes painted or 0·1 mil electrodeposited zinc (bare). The C.R.L. and A.R.E. tests gave similar results except that, in the C.R.L. test, 0·1 mil electrodeposited zinc (bare) gave an inferior result to phosphating and painting. This last result is interesting, as a similar result for a 0·3 mil electrodeposited zinc coating (bare) was obtained after a 5-yr. field test at Birmingham.

These conclusions, however, can only be regarded as tentative, based as they are on visual observations and pending the results of longer periods of exposure in the field tests followed by a determination of actual weights lost due to rusting.

Dr. **F. A. Champion** (British Aluminium Co., Ltd.): I would point out that, if the zinc coating results are excluded, better correlation is given between the two laboratory tests as compared with the field tests (considering order of merit).

The revision of the correlation between laboratory and field tests from the First Report, as given in Table XXI, has resulted in a marked fall in the ranking coefficient for the A.R.E. test. Has this been taken into account in paragraph (iii) of the summary (p. 270), in which it is stated that the results of outdoor tests on industrial protective schemes confirm the conclusion that the A.R.E. salt drop test gives a reasonable indication of service performance? It is rather surprising that the sea-water test can give so much information on field tests, which I assume are all essentially urban or industrial, and it is significant that the two tests on which the correlation coefficients have improved (and are now markedly better than for the A.R.E. test) are the intermittent spray test (which incorporates sulphates and chloride, drying, and ultra-violet radiation) and the accelerated weathering test (which involves SO_2 and ultra-violet radiation). There is other evidence suggesting that chlorides play a significant rôle in conjunction with SO_2 in industrial environments, and the C.R.L. test could perhaps be improved by including some chloride. The radiation effects would no doubt apply only to paint films.

Are all the correlation coefficients given in the paper and appendix ranking coefficients and not with respect to actual values? This would make a great deal of difference in the interpretation of the results.

The first conclusion on p. 272 indicates that one can inhibit mineral acids to prevent attack on ferrous metals while not seriously affecting their attack on non-ferrous metals as used for the coatings. I find this surprising, and would welcome some information on the types of inhibitor intended.

Can Dr. Hudson give us some indication of the composition of the coating metals? I am thinking particularly of the aluminium, which is now regarded as having blistered. There is, I believe, no note to that effect on the shorter exposure tests in the first Report.

Mr. **R. J. Brown** (Morris Motors, Ltd.): I agree with Dr. Hudson that the results of accelerated performance tests where corrosion is concerned with the breakdown of protective films are very discouraging. The lack of reproducibility of results within a laboratory and also between laboratories is astounding, even when all the factors involved in the test are, so far as is known, under control.

The test in which specimens were first intentionally damaged affords a measure of the ductility of the coating and of the adherence of the coating to the metal beneath. It would therefore be difficult to specify a precise degree of damage that would give satisfactory accelerated tests for performance.

I am surprised at the success of the phosphate coating, and would like some information on the type of coating applied. Generally, in works practice, the control of the quality of phosphate coatings is achieved largely on the basis of appearance; for example, a line inspector judges the success of the phosphate treatment by the crystalline appearance of the coating and any apparent dustiness. This is purely process control, but it seems to me to be exceptionally easy. However, a more precise test for performance is certainly required, to ensure that one is not misled by the appearance of the work.

I confirm the very great possibilities of the C.R.L. beaker test. It is surprising how few industrial laboratories have investigated the possibilities of this method of testing, particularly when one considers that a new unit costs only about £15. Our experience with the C.R.L. tests has been essentially with temporary protectives based upon wool grease, and with electrodeposited coatings on steel. Where electrodeposited coatings have been tested, sulphur dioxide has been produced in accordance with the regular C.R.L. procedure using sulphurous acid, whereas with the temporary protectives the sulphur dioxide has been produced by the modified means (due, I believe, to C.R.L.) of adding sulphuric acid to a solution of sodium thiosulphate contained in a beaker.

With the electrodeposited coatings, our experience has shown reasonable correlation between outdoor weathering and the beaker test; but with the temporary protectives, although the results are interesting, correlation is not entirely satisfactory, owing to the relative rapidity of breakdown of the protective film. One reason which we believe accounts for the rapidity of breakdown is the difficulty of achieving uniform distribution of the

SO_2 in the atmosphere within the beaker at the time of adding the sulphuric acid. Unless very great care is exercised, a local concentration of SO_2 occurs towards one side of the beaker, and this definitely upsets the comparative nature of the tests. Perhaps Mr. Preston can comment on this matter, but so far we have not been able entirely to overcome the difficulty.

I would like to suggest the possibility of standardizing control for phosphate coatings by crystal size and crystal formation. We know that crystal size and crystal form are governed, to some extent, by the pre-treatment of the metal. Also, is there any possibility of relating the electrical properties of the coating, assuming that they can be determined, to the performance characteristics of the coating ?

Mr. **R. St. J. Preston** (Chemical Research Laboratory): Mr. Drysdale referred to the fact that correlation between laboratories using the beaker test was not as good as it should be. I believe this may relate to an odd result in which agreement between two laboratories was not good. One result differing so widely from the rest of a number may be regarded as extraneous in a general statistical survey; such a result is normally discarded. I would like to make it clear that the correlation between the C.R.L. test and atmospheric exposure results is fairly good after 3 months' exposure, and considering that the co-operating laboratories were using the test for the first time the agreement between them was as good as could be expected.

The modifications mentioned by Mr. Drysdale were made, at the suggestion of Dr. Hudson and the Committee, to accommodate more samples; they consisted of the substitution of a 5-litre beaker for the 3-litre beaker previously used, and a new type of specimen holder designed for twelve 6 in. × 2 in. specimens arranged radially. The cooling coil was changed for simplification in manufacture.

I would like to call attention to another slight change in operating method being examined by the Temporary Protectives Panel of the Institute of Petroleum, under the Chairmanship of Mr. Steet, who suggested using a stable salt (sodium thiosulphate) and acid to produce the sulphur dioxide. Results obtained by members of the panel and by Mr. Stroud in my laboratory have shown a decided improvement in the reproducibility between laboratories.

Dr. Champion spoke of the improvement resulting from the addition of hydrochloric acid to the beaker. I would confirm this when aluminium is the metal under test. One laboratory using the method with SO_2 only for testing aluminium and its alloys found the corrosion to be of a different type from that obtained from outdoor tests in an industrial atmosphere. With the addition of hydrochloric acid, however, the pitting type of attack that was observed in outdoor exposure tests developed also in the laboratory test.

Mr. Brown mentioned the problem of local attack when using sodium thiosulphate as a source of sulphur dioxide for testing temporary protectives. This difficulty might be overcome by turning the stand with its specimens in the beaker several times while the sulphur dioxide is being generated in the first few minutes after the addition of acid. I should mention that it is desirable to turn and reverse the specimens at least daily.

AUTHOR'S REPLY

Dr. **J. C. Hudson** said in reply: I wish to thank Mr. Drysdale and the other speakers for their kind remarks about the work of the Sub-Committee. We have the utmost sympathy with his suggestion that we should publish a popular account of the results of our researches, and will bear this in mind for action at the appropriate moment.

Mr. Drysdale enquired whether there were unavoidable variations in the degree of damage inflicted on the specimens before testing. Arrangements were made for all the specimens used for the investigation of the C.R.L. test to be damaged in my laboratory before they were sorted into sets and sent to the laboratories of other Sub-Committee members for the corrosion tests. Although we did not randomize the specimens, but treated sets of specimens of the same coating together, I am satisfied that the damage was reasonably reproducible, as in fact is demonstrated by some of the results given in the Report. I feel, with Mr. Drysdale, that the main reason for the discrepant observations from one laboratory to another was lack of experience of this new method of testing. To this should be added the factor mentioned by Mr. Brimelow; namely, the difficulty of distinguishing traces of rust-staining on certain surfaces. It is probable that much better reproducibility would be observed if we repeated the investigation of the C.R.L. test. It must be remembered that the variety of coatings tested was extremely wide. Indeed, Mr. Brimelow and Dr. Champion have both suggested that the reproducibility would be increased if certain coatings were omitted. This is true, but naturally we thought it preferable to calculate the correlation coefficients on the results actually obtained. The lack of reproducibility for the sprayed aluminium coatings is largely due to the spread of rust-staining from the cut edges, caused by the drainage of condensed water under gravity.

Mr. Preston has already replied to various questions about the technique of the C.R.L. test; as he said, several modifications have been made in this since the collaborative work of the Sub-Committee was undertaken, and these modifications are all improvements that should tend to increase the reproducibility of the test.

We do not propose to repeat this particular investigation of the C.R.L. test because, now that it has been standardized, a more mature judgment as to its value and suitability will become possible in a few years' time on the basis of its use in industrial laboratories. On this point, I am glad to learn from Mr. Brown that he has already found it of help for his purposes.

In reply to Dr. Champion, the correlation coefficients given in this Report were computed by Spearman's ranking method; this is an easy and fairly rapid method of correlation, which we think adequate for our purpose. The aluminium used for the sprayed aluminium coatings was of normal commercial quality and presumably contained about 99·5% of aluminium.

Mr. Brown will find particulars of the phosphating processes used for the C.R.L. test specimens in the right-hand column of p. 256 of the Report; I may add to this information that both the baths were of the accelerated zinc phosphate type. His suggestion that the grain size of phosphate coatings might be used for standardization purposes is an interesting one; we will bear it in mind.

N E W S

ANNOUNCEMENTS AND NEWS OF SCIENCE AND INDUSTRY

THE IRON AND STEEL INSTITUTE

Annual General Meeting, 1953

The **Annual General Meeting** of The Iron and Steel Institute will be held at 4 Grosvenor Gardens, London, S.W.1, on **Thursday 30th April and Friday 1st May, 1953.** Details of the programme will be given in a later issue of the *Journal*.

Special Meeting on Boron in Steel

A Special Meeting will be held on **Wednesday, 18th February, 1953,** at the offices of the Institute, 4 Grosvenor Gardens, London, S.W.1, to discuss recent developments in the U.S.A. in the manufacture and use of boron-bearing steels. The President, Capt. H. Leighton Davies, will be in the Chair.

The meeting has been arranged by the Institute at the suggestion of the Ministry of Supply, acting in conjunction with the Organization for European Economic Co-operation.

The following two papers will be presented for discussion:

"Manufacture of Boron Steels," by N. F. Tisdale (Molybdenum Corporation of America)
and **"Use of Boron Steel,"** by H. B. Knowlton (International Harvester Company).

A Buffet Luncheon will be arranged in the Institute Library, and there will be an interval during the morning for light refreshments.

Programme

Morning Session—devoted to the use of boron in steelmaking
9.45 A.M. to 12.45 P.M.—Presentation of Mr. Tisdale's paper, followed by discussion
11.0 A.M. (approx.)—Interval for light refreshments
12.45 P.M. to 1.45 P.M.—Buffet Luncheon

Afternoon Session—devoted to the application and use of boron-bearing steels
1.45 P.M. to 4.45 P.M.—Presentation of the paper by Mr. Knowlton, followed by discussion.

NEWS OF MEMBERS

▶ Mr. G. R. BISH has taken up an appointment as metallurgist to Enfield Cables Ltd.

▶ Dr. J. H. CHESTERS is to receive the Hunt Award from the American Institute of Mining and Metallurgical Engineers for his paper on "Flow Patterns in Open-Hearth Furnaces," presented at Cleveland in 1951.

▶ Mr. D. R. G. DAVIES has resigned from the position of Chief Metallurgist at the Redbourn Works of Richard Thomas and Baldwins Ltd., and has joined the Workington Iron and Steel Company, Workington, as Control Metallurgist and Chief Chemist.

▶ Mr. N. R. DUTT has left Martin Burn Ltd. to join the Steel Corporation of Bengal, India.

▶ Mr. CURT ERICSSON has taken up an appointment as Chief Metallurgist at Surahammars Bruks A.B., Sweden.

▶ Mr. W. C. FAHIE is no longer acting for Tinsley Industrial Instruments Ltd., London.

▶ Dr. F. A. FOX has joined the Australian Government Department of Supply as Superintending Scientist in charge of the Department's Chemical and Physical Research Laboratories at Maribyrnong, Victoria. The B.W.R.A. Headquarters were used as an accommodation address before his departure, and Dr. Fox had not rejoined the Association as reported in the December, 1952, issue of the *Journal*.

▶ Mr. P. S. MATHUR has left Mannesmann-Hüttenwerke A.G., Duisburg-Huckingen, and has joined the Blast-Furnace Department of Dortmund-Hörde Hüttenunion, West Germany.

▶ Professor R. F. MEHL has been awarded the Gold Medal of the American Society for Metals.

▶ Mr. J. A. MENZIES has taken up an appointment with the Consolidated Pneumatic Tool Co., Ltd., Aberdeen.

▶ Mr. P. J. ROWLING has been appointed Metallurgist to the Massey-Harris Co., Ltd., Kilmarnock, Ayrshire.

▶ Mr. P. SAMUEL, who has joined the Research Laboratories of Hadfields Ltd., has been awarded the degree of Ph.D. in Metallurgy of the University of Sheffield.

▶ Professor CYRIL STANLEY SMITH, Director of the Institute for the Study of Metals at the University of Chicago, Illinois, is planning a visit to various metallurgical research centres in England and Western Europe in February and March, 1953.

▶ Mr. E. J. D. SMITH has left the Refractories Section of the British Iron and Steel Research Association to join the Research Laboratories of the British Electricity Authority at Leatherhead, where he will be responsible for metallurgy and ceramics as applied to the electricity undertaking.

▶ Mr. B. N. H. THORNELY has left Aluminium Ltd., Montreal, to return to the Northern Aluminium Co., Ltd., London.

▶ Mr. J. F. WHITFIELD has relinquished his post as Chief Engineer of Birmetals Ltd. to take up the appointment of General Manager of B. Thornton Ltd., Huddersfield.

▶ Mr. A. B. WINTERBOTTOM has left the Metallurgist Institutt, Norges Tekniske Hogskole, Trondheim, Norway, to take up the appointment of Professor of Metallurgy at the University in Dacca, Pakistan, for one year.

New Year's Honours

▶ Mr. G. LL. HOPKIN, Senior Principal Scientific Officer, Ministry of Supply, has been awarded the O.B.E.

▶ Mr. H. S. JONES, Chief Engineer of Round Oak Steel Works, Ltd., Brierley Hill, Staffs., has been awarded the M.B.E.

▶ Mr. T. KIRKUP, General Manager of Steetley Magnesite Co., Ltd., Hartlepool, Co. Durham, has been awarded the M.B.E.

▶ Mr. B. L. NEWBOULD, Manager of the Steel Melting Department of Thos. Firth and John Brown Ltd., Sheffield, has been awarded the M.B.E.

Obituary

Mr. J. S. BOWDEN, a senior metallurgist at the Tin Research Institute, Greenford, Middlesex, on 28th November, 1952.

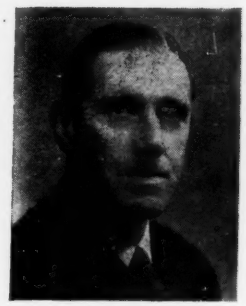
Mr. HENRY S. LEVICK, Chairman of Swift Levick and Sons Ltd., Sheffield, on 4th November, 1952.

Mr. EDWIN SYKES, Director of John Sykes and Sons Ltd., Huddersfield, and of George Burns and Sons Ltd., Galashiels, on 13th October, 1952.

CONTRIBUTORS TO THE JOURNAL

G. Barry Thomas—Director and General Works Manager, Cargo Fleet Iron Co., Ltd., Middlesbrough.

Mr. Thomas was educated at Middlesbrough High School and at St. Peter's School, York. He joined the Cargo Fleet Iron Company in 1919 as Trainee in the Laboratory. After gaining experience in the Drawing Office, Fitting Shop, General Maintenance Engineering, and Fuel Conservation Departments, he transferred to Blast Furnaces, Melting Shop and Mills, and became Mills Manager in 1932. Six years later he was appointed Assistant General Works Manager, and in 1946 he became General Works Manager. He was appointed to the Board of the Company in 1950.



G. B. Thomas

Mr. Thomas is a member of the Council and past-President of the Cleveland Institution of Engineers, and is a member of Council of the Cleveland Scientific and Technical Institution. He has been a Member of The Iron and Steel Institute since 1934.

R. A. Smith, B.Sc., Ph.D., A.I.M.—Development and Research Department, The Mond Nickel Co., Ltd.

Mr. Smith was born in 1926. He was educated at Holly Lodge Grammar School, Smethwick, and at the University of Birmingham, where he graduated with Honours in 1946. He was awarded the degree of Ph.D. of the University in 1950, and took up his present appointment early in 1951.

IRON AND STEEL ENGINEERS GROUP

The **Twenty-Second Meeting** of the Group will be held at 4 Grosvenor Gardens, London, S.W.1, on **Thursday, 19th March, 1953,** instead of Wednesday, 18th March, as previously announced. A Buffet Luncheon will be held in the Library.

The two papers to be presented for discussion are on the Electric Distribution System at the Abbey and Margam Works of the Steel Company of Wales Ltd., by T. B. Rolls and E. C. Slater (*see this issue*, pp. 163–176), and on Industrial Electric Furnaces, by J. C. Howard (*to be published in the March issue of the Journal*).

BRITISH IRON AND STEEL RESEARCH ASSOCIATION

Some minor administrative changes have been made within the Association to provide a closer liaison between sections investigating similar problems. The Fuel Section of the Plant Engineering Division is now merged with the Heat and Thermodynamics Section of the Physics Department, and is under the control of that Department.

The Open-Hearth and Industrial Experimental Sections of the Steelmaking Division are now combined. The new Section will deal with 'hot-model' work and field trials, and will apply to industrial problems the recent advances in the knowledge of heat transfer and aerodynamics.

INSTITUTE OF METALS

Spring Meeting

The Annual General Meeting will be held in London on Monday–Thursday, 23rd–26th March, 1953. The 43rd Annual May Lecture, on "The Present and Future Metallurgical Requirements of the Chemical Engineer," will be given by Sir Christopher Hinton on 23rd March at the Royal Institution, Albemarle Street, W.1, at 6.0 p.m. The remainder of the scientific and technical sessions will be held at the Park Lane Hotel, Piccadilly, W.1. On the evening of Wednesday, 25th March, a Conversazione and Exhibition will be held at the Institute's headquarters at 4 Grosvenor Gardens, S.W.1.

Award of Medals

The Council of the Institute of Metals has made the following awards of medals for 1953:

THE INSTITUTE OF METALS (PLATINUM) MEDAL to Professor GEORG MASING, of the Institut für Allgemeine Metallkunde, Universitat Göttingen, in recognition of his outstanding contributions in the field of metallography.

THE ROSENHAIN MEDAL to Dr. CHARLES ERIC RANSLEY, of the Research Laboratories, The British Aluminium Co., Ltd., Gerrards Cross, in recognition of his outstanding experimental and theoretical work on gas–metal equilibria.

EDUCATION

New Training Scheme for Foremen

Hadfields Ltd. are introducing a new scheme for the further intensive training of their Foremen. Tuition will be given on such subjects as work study, productivity, quality control, and the conservation of man-power, materials, and machine tools.

The inauguration of this scheme marks a further step in the training of employees of the company. Already more than one hundred Apprentices are being trained under the guidance of a Training Officer and other skilled instructors.

Training in Britain of Engineers from Latin America

The Federation of British Industries has recently published a report on the British Engineering Training Mission to Latin America, May–July, 1952.

The report recommends a major extension of training facilities for overseas engineers in Britain, which would necessitate a considerable increase in the number of firms already participating in the F.B.I. Scholarships Scheme. The Mission believes that in this way Britain would get her share of the large contracts for capital equipment which would be placed by developing countries in future years.

The Report may be obtained from the Federation of British Industries, 21 Tothill Street, London, S.W.1, at 7*s.* 6*d.* per copy.

NEWS OF SCIENCE AND INDUSTRY

H.R.H. The Duke of Edinburgh

The Council of the Institution of Metallurgists have great pleasure in announcing that His Royal Highness The Duke of Edinburgh has graciously accepted election to Honorary Membership of the Institution.

His Royal Highness also has graciously accepted election to Honorary Membership of the Institution of Mining and Metallurgy.

Fifth Liège International Fair

The 5th Liège International Fair will be held from 25th April to 10th May, 1953. The Sessions will take place in the Salle Académique of Liège University, Place du XX Août, Liège. Included in the programme are conferences on the low-shaft furnace and on the basic Bessemer converter, organized by Le Centre National de Recherches Métallurgiques (Section Liègeoise), La Société Française de Métallurgie, Das Verein Deutscher Eisenhüttenleute, and The Iron and Steel Institute. Details may be obtained from Monsieur Paul M. Lejeune, Foire International de Liège, 17 Boulevard d'Avroy, Liège, Belgium.

Conference on Deep Drawing of Metals and Continuous Casting of Ingots

The Department of Industrial Metallurgy, University of Birmingham, will hold its Annual Conference on Monday and Tuesday, 16th and 17th March, 1953. The subjects will be "The Deep Drawing of Metals" on 16th March and "Continuous Casting of Ingots" on 17th March. Full details of the programme may be obtained from the Secretary, Department of Industrial Metallurgy, The University, Edgbaston, Birmingham 15. There will be no charge for admission, but registration is required.

First Latin American Metallurgical Conference at Bogota, Colombia, 13th–31st October, 1952

Mr. F. H. Saniter (United Steel Companies, Ltd.) reports that this Conference, organized by the Economic Commission for Latin America and the Technical Assistant Administration of the United Nations, was well attended by representatives from the Latin American countries, the U.S.A., Canada, France, W. Germany, Belgium, Switzerland, Sweden, and Norway. Some 70 papers were presented, covering coal, coke, the reduction of iron ore, steelmaking, manipulation, economics, and location. The average standard was high and in most cases the authors, who were leading figures in their particular fields, presented the papers in person.

Since, with the exception of Mexico and Colombia, the Latin American countries are deficient in coking coal, particular attention was paid to the cleaning of coal and the problem of making metallurgical coke from indifferent raw material. For the same reason, processes for the reduction of ore by methods other than the conventional blast-furnace were reviewed in considerable detail. Papers were presented which dealt with nearly all the well-established steelmaking processes, particular emphasis being given to Thomas steel and the efforts which were being made in Europe to improve its quality. Rolling and forging were not considered in detail, but some attention was paid to extrusion and continuous casting since both of these are new processes which may be of interest to a developing industry. A number of excellent papers relating to the economics and location of iron and steel manufacture in Latin America were presented by the E.C.L.A. staff.

This was the first occasion on which those interested in the production of iron and steel in Latin America had been brought together, and at the same time they were provided with the opportunity of meeting many metallurgists and engineers of high standing from North America and Europe. Although the Conference could not be expected to produce any very definite recommendations or conclusions, it should help towards ensuring that future developments are soundly based. Consideration will be given to the formation of a Latin American Coal, Iron and Steel Institute, so as to foster co-operation in the future.

Mond Nickel Fellowships

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The need for continuing and extending economy in the use of alloying and non-ferrous metals is emphasized in the first Report of the Metals Economy Advisory Committee, which was set up by the Minister of Supply in conjunction with the Minister of Materials in August, 1951, to study ways in which scarce metals could be saved in industry. There is, at present, little margin in estimated supplies of these metals to meet unforeseen demands, or to build up stocks to offset any possible shortfalls in supply due to causes outside the United Kingdom's control.

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The Institute of Physics has provided a short bibliography of information on the subject, and it is recommended that more specific information should be obtained from the following sources: The Director, National Physical Laboratories, Teddington, Middlesex; the Chief Inspector of Factories, 8 St. James's Square, London, S.W.1; or (regarding the use of radioactive isotopes) the Director, Atomic Energy Research Establishment, Harwell, Didcot, Berks.

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DIARY

2nd Feb.—CLEVELAND INSTITUTION OF ENGINEERS—"*Gas Turbines and their Applications in Iron and Steel Works*," by F. E. Baumann—Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, 6.30 P.M.

2nd Feb.—INSTITUTE OF BRITISH FOUNDRYMEN—Sub-Committee T.S. 35's Film: "Flow of Metal"—Sheffield College of Commerce and Technology, Department of Engineering, Pond Street, Sheffield 1, 7.30 P.M.

3rd Feb.—EBBW VALE METALLURGICAL SOCIETY—"*Steel Works Electrical Equipment and its Maintenance*," by J. T. Mills—Lecture Room, Richard Thomas and Baldwins Ltd., Ebbw Vale, 7.15 P.M.

4th Feb.—MANCHESTER METALLURGICAL SOCIETY—"*Some New Laboratory Techniques*," by F. Ashworth, F. G. Haynes, and J. Johnson—Engineers' Club, Albert Square, Manchester, 6.30 P.M.

5th Feb.—SOCIETY OF CHEMICAL INDUSTRY—"*Atmospheric Corrosion and Atmospheric Pollution*," by J. C. Hudson and J. F. Stanners—Gas Showrooms, Parliament Street, Nottingham, 7.15 P.M.

8th Feb.—LEEDS METALLURGICAL SOCIETY—"*The Continuous Casting Processes*," by E. Scheuer—Chemistry Department, The University, Leeds 2, 7.0 P.M.

9th Feb.—INSTITUTION OF PRODUCTION ENGINEERS—"*Modern Cold-Rolling Mills*," by G. Ashton—Royal Victoria Station Hotel, Sheffield, 6.30 P.M.

9th Feb.—SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS—SHEFFIELD METALLURGICAL SOCIETY—LEEDS METALLURGICAL SOCIETY—Talk on the Productivity Team Report, by Sir Charles Goodeve—Mappin Hall, University Building, St. George's Square, Sheffield, 7.0 P.M.

12th Feb.—LIVERPOOL METALLURGICAL SOCIETY—"*Nucleation in Metals and Alloys*," by J. H. O. Varley—Liverpool Engineering Society, The Temple, Dale Street, Liverpool, 6.30 P.M.

12th Feb.—NEWPORT AND DISTRICT METALLURGICAL SOCIETY—"*The Presentation of Data and Industrial Efficiency*," by B. Dudding—Whitehead Institute, Cardiff Road, Newport, 7.0 P.M.

12th Feb.—STAFFORDSHIRE IRON AND STEEL INSTITUTE—"*Mechanical Testing*," by A. Honeyman—Star and Garter Hotel, Wolverhampton, 7.30 P.M.

14th Feb.—SWANSEA AND DISTRICT METALLURGICAL SOCIETY—"*Deep Drawing of Steel from the Point of View of the User*," by G. Murray—Central Library, Swansea, 6.30 P.M.

16th Feb.—CLEVELAND INSTITUTION OF ENGINEERS—"*Some Factors Affecting the Performance of an Open-Hearth Steelplant (with particular reference to Redcar practice)*," by J. S. Curphey—Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, 6.30 P.M.

16th Feb.—SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS (Joint Meeting with Sheffield Metallurgical Association and Institute of Metals)—"*The Constitution and Properties of Some Titanium-Base Alloys*," by W. A. Baker—The University Building, St. George's Square, Sheffield, 7.0 P.M.

18th Feb.—THE IRON AND STEEL INSTITUTE—Discussion on Boron in Steel—4 Grosvenor Gardens, London, S.W.1.

18th Feb.—NORTH WALES METALLURGICAL SOCIETY—"*Radioactive Tracer Techniques*," by H. M. Finniston—County Primary School, Plymouth Street, Shotton, Nr. Chester, 7.15 P.M.

18th Feb.—SOCIETY OF CHEMICAL INDUSTRY—"*Some Recent Advances in Corrosion Research*," by W. H. J. Vernon (2.30 P.M.), and "*Protective Coatings for Buried Pipelines*," by K. A. Spencer and H. B. Footner (6.0 P.M.)—The Stephenson Building, King's College, Newcastle-on-Tyne.

18th Feb.—MANCHESTER METALLURGICAL SOCIETY—"*Metallurgical Aspects of Lubricating Problems*," by A. L. H. Perry—Engineers' Club, Albert Square, Manchester, 6.30 P.M.

20th Feb.—INSTITUTION OF PRODUCTION ENGINEERS—"*Efficient Production Methods Applied to Iron Founding*," by G. W. Nicholls—Town Hall, Hanley, Stoke-on-Trent, 7.30 P.M.

26th Feb.—STAFFORDSHIRE IRON AND STEEL INSTITUTE—"*Some Aspects of the Problem of Maintenance*," by G. C. Oram—Wolverhampton and Staffordshire Technical College, Wolverhampton, 7.30 P.M.

27th Feb.—NORTH EAST METALLURGICAL SOCIETY—"*Steelfoundry Radiographic Practice*," by G. M. Michie—Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, 7.15 P.M.

TRANSLATION SERVICE

(The previous announcement was made in the January, 1953, issue of the *Journal*, p. 88.)

TRANSLATIONS AVAILABLE

No. 459 (German). H. BARKING and C. EYMANN: "On the Production, Gasification and Smelting of Iron-Rich Coke in the Making of Lean Gas." (*Glückauf*, 1952, vol. 88, Nov. 8, pp. 1090–1094).

No. 460 (Polish). E. TERLECKI: "New Views on the Method of Heating Steel for Plastic Working." (*Hutnik* (*Katowice*), 1952, vol. 19, No. 2, pp. 37–42).

No. 461 (German). L. HÜTTER: "Progress in the Basic Lining of Open-Hearth Furnaces." (*Stahl und Eisen*, 1952, vol. 72, Oct. 9, pp. 1285–1293). (Translation prepared by and made available through the courtesy of The British Iron and Steel Research Association. Members of the Association may obtain copies free of charge on application to B.I.S.R.A.).

TRANSLATIONS IN COURSE OF PREPARATION

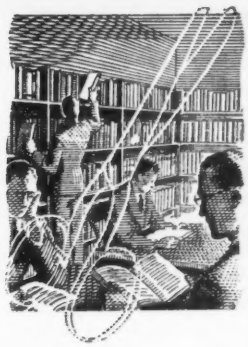
(German). A. SEND and F. STRÄHUBER: "Determination of the Heat Losses from Blast-Furnaces by Measurements on the Cooling Water." (*Stahl und Eisen*, 1952, vol. 72, Nov. 20, pp. 1509–1512).

(German). W. HEISCHKEIL: "Influence of the Manufacturing Conditions in the Steel Plant on the Quality of Forging-Grade Steel Ingots." (*Stahl und Eisen*, 1952, vol. 72, June 5, pp. 663–668).

CHARGES FOR COPIES OF TRANSLATIONS—The charge for translations is £1 for the first copy and 10*s.* for each additional copy of the same translation. Requests should be accompanied by a remittance. These translations are not available on loan from the Joint Library.

TRANSLATIONS PREPARED AT MEMBERS' REQUESTS—Members requiring translations of foreign papers are invited to communicate with the Secretary, who will ascertain whether they can be prepared for inclusion in the Series.

ABSTRACTS AND BOOK NOTICES



IRON AND STEEL MANUFACTURE AND RELATED SUBJECTS

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MINERAL RESOURCES

The Iron Ore Position. (*Metallurgia*, 1952, **46**, Aug., 79–82). The prospects of future world supplies of iron ore are discussed with regard to quality, accessibility, and quantity. Estimated quantities of the main Pre-Cambrian and Post-Archaean sedimentary ore reserves are given. The immediate prospects in Great Britain, with particular reference to the plans for increased pig iron production, are reviewed.—B. G. B.

Iron and Steel—The Importance of New Ore Deposits. (*Min. J.*, 1952, **239**, Oct., 402–403). The total world demand (excluding the U.S.S.R.) for iron ore is expected to increase by about 60% by 1975, but the dependence of the U.S.A. on imported ore is expected to increase very substantially by then. The availiable ore resources are discussed. The deposits in Labrador, Venezuela, Chile, and Liberia will probably meet this American demand.—B. G. B.

Newfoundland Explores Its Mineral Wealth. G. G. Thomas. (*Min. Eng.*, 1952, **4**, July, 672–673). Much prospecting and exploration of minerals have occurred since confederation with Canada. The most important developments are at Buchans (production of lead, zinc, and copper concentrates), Bell Island (working and submarine mining of Wabana iron ore), and Labrador–New-Quebec (iron ore and native copper). Other minerals are mentioned.—K. E. J.

Steep Rock's Huge Reserve an Ace for Canada's Future. M. S. Fotheringham. (*Eng. Min. J.*, 1952, **153**, Apr. 82–85). Technical and economic factors in the development of Canada's reserves of high-grade iron ores are discussed. It is envisaged that Canada's steel industry will expand, and also that ore exports to the U.S.A. and elsewhere will greatly increase. Over 10^9 tons of ore are estimated to exist at Steep Rock, and details of the various exploration areas are given. The Seine River has been diverted, and Steep Rock Lake (7 sq. miles in area) dewatered. Annual ore production rate in 1953 may reach 4×10^6 tons.—K. E. J.

Some Modern Methods of Coal Investigation as Applied to Queensland Coals. O. A. Jones. (*Proc. Australasian Inst. Min. Met.*, 1950, Sept.–Dec., 345–366). It is only recently that a start has been made on a thorough investigation of Queensland coals. The author outlines the modern methods of coal investigation and comments on the probable application of the techniques and, where possible, gives examples for this area. The reserves of coking coals may be small.

The Genesis of Oolitic Lorraine Ores in Relation to the State of the Iron, and the Chronological and Spatial Unity of Their Evolution. S. Caillère and F. Kraut. (*Compt. Rend.*, 1952, **235**, Sept. 1, 510–511). From top to bottom the layers of ore are red, yellow, grey, brown, black, and green, and consist of carbonate, oxide, and silicate ores. The iron is more reduced in lower layers, and in any layer the oolites are more oxidized than the gangue. The common background of oolites, having the same composition as the individual envelopes, is contrary to the idea of the transport of the oolites with subsequent deposition.—A. G.

The Mineral Resources of the Central Pyrenees. V. Charrin. (*Génie Civil*, 1952, **129**, July 1, 243–248). The geology of the Departments of Ariège, Haute Garonne, and Hautes-Pyrénées is described in some detail. Hematite, limonite, and iron carbonate ores are found. Manganese ore was worked out in 1926. Pyrites and ores of copper, antimony, lead, and zinc occur. Very little coal exists but some natural gas is distributed by nearly 1000 km. of pipelines to domestic and industrial consumers in S.W. France.—T. E. D.

The Mineral Resources of the Departments of Avignon and Tarn. V. Charrin. (*Génie Civil*, 1952, **129**, Sept. 15, 346–350). The locations of metal-bearing minerals, including hematite, pyrites, and manganese ores are described, and early lead, silver, and copper workings are mentioned. The very rich Aubin-Decazeville coal basin is included, and also the coalfields of Carmaux and Albi. Geological maps are shown.—T. E. D.

Manganese Deposits in India: Some Geological and Metallurgical Features. (*Iron Coal Trades Rev.*, 1952, **165**, Sept. 12, 599). A brief description is given of the type, quality, and location of manganese ore deposits in India. The major portion of the high-grade ores is exported. Because of their high manganese content, the ores do not require beneficiation.—G.F.

The Manganese Ore Deposits of Western Bulgaria. W. E. Petrascheck. (*Metall u. Erz*, 1940, **37**, Mar., No. 6, 101–104). The geology of the Western Bulgarian deposits of manganese ore is described. Some of the deposits are sedimentary, others are formed by the metasomatic displacement of the marly limestones. The ores are unusually low in iron content.

The Ore and Metal Resources of Scandinavia, and Their Importance to the War Economy. (*Metall u. Erz*, 1940, **37**, May, No. 9, 182–187). Statistics are given of Scandinavian production, in the years immediately preceding 1939, of ores, metals, and ferro-alloys.—L. H.

Sierra Leone. A. G. Thomson. (*Min. J.*, 1952, **239**, Aug., 197–198). A review is made of the mineral resources of Sierra Leone. In addition to the deposits of iron ore now being worked in the Marampa district, preparations are being made to work the Tonkolili deposits which are more extensive. Diamonds, gold, platinum, and chromite ore are also being worked.—B. G. B.

Liberia—The Bomi Hills Development. (*Min. Eng.*, 1952, **4,** July, 674–675). The ore of the Liberian Mining Co's mine at Bomi Hills is the richest in the world (68–69% Fe). Magnetite and hematite are associated with itabirite in a bowl formation. The ore mined is hard and dense, with few fines. Exploitation has been made possible by new railway construction, and the artificial harbour at Monrovia. The first shipment had a successful trial by Republic Steel Corp. in June 1952 at Cleveland. Present production is at a rate of 90,000 tons/month.—K. E. J.

Ungava Peninsula. A. Buisson. (*Min. Mag.*, 1952, **87,** Aug., 73–86). The geography and resources, and history of exploration and development, of the Labrador/New-Quebec area are outlined. Mineral resources include iron ore, copper–gold ores, asbestos, pyrite, lead–zinc, cobalt, mica, and graphite. The iron ore deposits indicate reserves of $4 \cdot 2 \times 10^8$ tons, approx. 50% assaying 60% Fe, while there is much material capable of beneficiation. Details of the concessions are given ; initial production should be 3×10^6 tons/year in 1954.—K. E. J.

Treasure Hunt in North Africa. M. Moyal. (*Mine Quarry Eng.*, 1952 **18,** Sept., 279–281). The author describes the activity throughout the area in surveying the mineral deposits, and initiating and developing schemes to exploit them. Oil, iron ore, coal, and a variety of non-ferrous metals (including manganese and cobalt) are among the projects mentioned.

The Provision of Ores and Metals for Greater East Asia. R. Dobransky. (*Metall. u. Erz*, 1944, **41,** June, No. 11–12, 137–141). The extent to which home resources and production of metals and ores meet the requirements of China, Korea, and Japan is reviewed with information on how the deficiencies are made good.—R. A. R.

Refractory Raw Materials of Barramyia. G. M. Gad. (*Trans. Brit. Cer. Soc.*, 1952, **51,** Sept., 429–437). Basic refractory materials and chromite deposits occur in the Barramyia mining district of Egypt. The mineral and chemical constitution of these raw materials has been studied and some results are reported.—E. C. S.

ORES—MINING AND TREATMENT

Handbook on Prospecting in South Australia. (*Dept. of Mines, S. Australia*, 1952). The subject matter is in four sections : (1) A brief account of the known mineral occurrences and their distribution ; (2) a description of methods of prospecting ; (3) the problem of treatment and marketing of minerals ; (4) an explanation of the legislation relating to the acquisition and working of mineral deposits.—J. C. B.

Mining and Metallurgical Education in Victoria. H. H. Dunkin and H. K. Worner. (*Proc. Australasian Inst. Mining and Metallurgy*, 1950, Sept.–Dec., 297–343).

The Selection and Use of Drill Steel. C. M. Cooley. (*Min. Eng.*, 1952, **4,** Jan., 43–46). Machine-drill efficiency must be measured by the bit-against-rock time. Properties of steels used for hollow drill rods (high-carbon, high-carbon alloy) low-carbon nickel alloy, and carbon vanadium alloy steels, are tabulated and described. Methods of determining rod life, stresses causing failures, metallurgical practices for improving the rod, and possibilities of drill rod as a single-use tool are discussed.—K. E. J.

The Use of P.V.C. in the Manufacture of Non-Inflammable Conveyor Belts. J. T. Barclay. (*National Coal Board Research Paper No.* 1, July, 1952). The problem of manufacturing a completely non-inflammable conveyor belting is examined. Tests are reported which show that a belt in which polyvinyl chloride (PVC) replaces the rubber in the covers and between plies is non-inflammable under all circumstances.—R. A. R.

Norwegian Ore Mining and Smelting Capacity. E. Sarcander. (*Metall u. Erz*, 1940, **37,** Oct., No. 19, 395–398). The article describes the natural resources of Norway and gives the output from 1936 to 1938 of iron ore concentrate (including titaniferrous ore) and of iron.—L. H.

Huge Expansion in Prospect for Iron Ore Beneficiation. L. A Roe. (*Eng. Min. J.*, 1951, **152,** Feb., 119–121). The American iron ore industry is handling approx. 25×10^6 tons of concentrates annually ; one-third of the ore used nationally is either beneficiated or agglomerated. The need for greatly increased use of taconite and pyrites deposits throws emphasis on these processes, and their materials handling problems. Current practice and trends are reviewed for heavy-media separation, gravity concentration, flotation, sintering, pelletizing, nodulizing, and several chemical beneficiation methods (leaching and acid solution).—K. E. J.

Blending of Bulk Raw Materials. A. E. Conover. (*Eng. Min. J.*, 1951, **152,** Dec., 97–99). The reduction of fluctuations in raw material feeds brought about by blending can show advantages of increased production, reduction of operating cost, improved quality of final product, and extension of reserves by controlled use of lower-grade material. Reclamation and bin-blending systems are described. The most successful, however, is bedding (the Robins–Messiter system) where successive cross-sectional increments are removed from beds made up of a large number of horizontally deposited layers of differing quality. Current installations will treat iron ores, copper concentrates and fluxes, and (in Britain) coals for coking.—K. E. J.

Radioactivity in Mineral Dressing. A. M. Gaudin. (*Min. J.*, 1952, **239,** Sept., 340–342). A number of examples of the use of radioactive isotopes in the investigation of mineral dressing processes are given. These include the study of the mechanism of flotation collectors, the genealcgy of broken fragments, and the sorting of radioactive materials.—B. G. B.

Impact Crushing for Reduction of Hard Abrasive Ores. W. W. West. (*Min. Eng.*, 1952, **4,** June, 563–564). Hammer-mills, in which both impact and attrition crushing occur, are suitable for fine grinding of non-abrasive substances. Impactors (not having the attrition stage) can be used for abrasive, wet, or frozen materials : the product is approximately cubical with a minimum of fines. Impactors are normally used in a closed circuit, with a circulating load. Operation and design factors are described.—K. E. J.

Influence of the Form of the Grinding Plates on the Performance of Ball Mills. O. Stein. (*Metall u. Erz.*, 1940, **37,** Mar., No. 6, 105–106). Chill-cast grinding plates, bolted to the casing of the mill, were cheap and easily replaced, but, unless very carefully heat-treated, they had a short working life. The addition of lifting ribs made from pit rails increased the life of the plates, but they, in turn, wore out quickly. Improvements in plate design, and the use of chromium and manganese steels are described.—L. H.

Modern Electro-Separators. H. B. Rüder. (*Metall u. Erz*, 1940, **37,** Sept., No. 18, 363–367). The author first outlines the difficulties which led to the failure of early attempts ; there were due partly to lack of suitable high-tension plant, and partly to the complicated problems connected with the electrical properties of the materials to be handled. Various types of apparatus are then described and illustrated, and the outlook for the further development of the process discussed.—L. H.

A New Method of Beneficiation of the Styrian Spathic Iron Ore. W. Luyken and L. Heller. (*Metall u. Erz.*, 1940, **37,** Mar., No. 5, 81–88). In the Styrian ores the carbamates of iron, calcium, and magnesium often form a series of solid solutions, which are separated by calcination, followed by magnetic concentration. This is only successful if the ore is decomposed in an atmosphere free from oxygen and rich in carbon dioxide, producing magnetic iron oxide. Techniques for achieving this are described.—L. H.

Taconite Plants, New Processes Come First in Iron Ore Plans. L. A. Roe. (*Eng. Min. J.*, 1952, **153,** Feb., 125–127). This is an account of pilot- and full-scale plants for iron ore beneficiation and treatment, constructed or planned during 1951 in the U.S.A. and elsewhere. The processes discussed include taconite treatment plants, pelletizing, flotation, heavy-media separation, jigging, cyclones, Humphreys spirals, magnetic separation, sintering, nodulizing, bound block production, sponge-iron plants, gaseous reduction, and Krupp-Renn rotary kilns.—K. E. J.

The Preparation of Mixes for Sintering. B. Sewerynski. (*Hutnik* (Katowice), 1952, **19,** 7–8, 271–273). [In Polish]. Methods of preparing sinter mixes, and equipment for mixing and charging are briefly surveyed.—V. G.

The Sintering of Iron Ores, Its Development in the Last Few Years and the Results of Own Researches. B. Sewerynski. (*Hutnik* (Katowice), 1952, **19,** 7–8, 260–267). [In Polish]. The factors influencing the development of sintering are outlined. General trends in the technology of sintering, such as : Increased suction, preparation of mixes to obtain self-fluxing sinters, two-layer sintering with varied content of carbon in each layer, the problem of bedding, and the methods of cooling the sinter are surveyed. The production of sinter

for use in open-hearth furnaces is briefly mentioned. The efficiency of the two main types of sinter plant (strand and pan) and developments in their design are discussed. (14 references).—B. G.

Instrumentation at Modern Ironmaking Plants—II. D. W. Gillings. (*Instrument Practice*, 1952, **6**, Sept., 756–767). Concluding part of a paper (*see J. Iron Steel Inst.*, 1953, **173**, Jan., 97). The author discusses the requirements of instrumentation for the control of moving grate and static grate sintering plants, and for the movement of blast-furnace raw materials. Some existing installations are described.—R. A. R.

Three-Phase A.C. Can Improve Fine-Size Magnetic Separation. S. Eketorp. (*Eng. Min. J.*, 1951, **152**, Oct., 82–83, 118). The operating principle of a new-type separator involves setting up a moving magnetic field in a pole piece which resembles the stator of an A.C. motor laid out flat. It operates best on at least −40-mesh ore. The magnetic portion of the ore clings to a non-magnetic division plate and is moved across the concentrates bin. Iron yields of over 98% are reported from several tests. (14 references).—K. E. J.

New Laboratory Apparatus for Magnetic Beneficiation. B. Granigg. (*Metall u. Erz*, 1940, **37**, Nov., No. 21, 425–432). For the satisfactory magnetic separation of fines it was found necessary to subject the material to strong vibrations. These were generated magnetically by the application of alternating current. Several types of apparatus using this principle are described and illustrated, and the results of experiments are given. A type of apparatus is also described, using a strong direct current, with mechanically produced vibration.—L. H.

Thoughts on Magnetic Roasting Problems. M. Mendez de Vigo, B. Chavarri, and J. Lopez-Varela. (*Inst. Hierro Acero*, 1952, **5**, Aug., 796–816). [In Spanish]. Magnetic roasting of iron ores tends to transform the natural oxides into the magnetic oxide. The theory of this transformation is discussed, starting with the analysis of the conditions of equilibrium of the various oxides of iron in oxidizing and reducing conditions. The authors consider whether there is any relationship between the magnetic state of the oxides and their state of oxidation, and indicate that possibly the magnetic transformation of the oxides is a physical change, a function of temperature, and does not directly depend on the degree of oxidation.—R. S.

The Preparation of High-Silica Iron Ores by the Krupp-Renn Process. F. Johannsen. (*Inst. Hierro Acero*, 1952, **5**, Aug., 787–795). [In Spanish]. The Krupp-Renn process offers a new way of separating the silica from the iron. The process is described and it is shown why it is specially suitable for high-silica ores. A rotary furnace plant is being installed in Spain to use Asturian ore and fuel.—R. S.

The Proportion of Foam Surface Area to Volume in Flotation Cells. W. Gründer and E. Kadur. (*Metall u. Erz*, 1940, **37**, Sept., No. 18, 367–372). Flotation experiments were carried out in celluloid cells, under carefully standardized conditions. The volume was increased in stages, (keeping the surface are a constant), using a standardized sludge, a flotation medium added, and air at a regulated pressure was blown through a perforated diaphragm at the base of the cell. Concentration and yield were plotted against time, and the results showed that the proportion of foam area to volume was unimportant. The law of mass action was applied to obtain the cell constant, and mathematically calculated curves were found to agree with those obtained experimentally.—L. H.

The Adsorption of Nuclear Gas.—Its Role in Froth Flotation. S. Wrobel. (*Mine Quarry Eng.*, 1952, **18**, Oct., 313–317). The author holds the view that the adsorption of air on to a conditioned mineral is the key to the ready attachment of large air bells of the size produced in flotation machines. He describes experiments designed to throw light on this view. The ease of air-bell formation, the rate of flotation, and the recovery of conditioned minerals was found to be influenced by the presence or absence of nuclear gas in the pulp.

Measurement and Evaluation of the Rate of Flotation as a Function of Particle Size. T. M. Morris. (*Min. Eng.*, 1952, **4**, Aug., 794–798). An attempt has been made to explain quantitatively the rate of flotation by a rate equation, and the effect of size on flotation rate is then considered. The flotation rate constant increases with particle diameter in the size range less than the optimum particle size; it then decreases; the two opposing mechanisms are discussed. Suggestions for further work in improving flotation rate of both fine and coarse particles are made.—K. E. J.

The Effect of Certain Starches on Quartz and Hematite Suspensions. S. R. B. Cooke, N. F. Schulz, and E. W. Lindroos. (*Min. Eng.*, 1952, **4**, July, 697–698). An aminoethyl derivative of whole corn starch was found to be an effective flocculent for aqueous suspensions of fine quartz and hematite, although ordinary starches are not good flocculents for quartz. The aminoethyl group allows more ready adsorption. The aminoethyl starch depressed both hematite and quartz in cationic flotation. The results are of interest in flocculation of tailing water, and pulps, and in processing of coal slimes and ores.—K. E. J.

High-Efficiency Desliming by Use of Hydraulic Water Additions to the Liquid-Solid Cyclone. D. A. Dahlstrom. (*Min. Eng.*, 1952, **4**, Aug., 788–793). The feasibility of hydraulic water cyclones has been proved, and desliming coefficients of 0·3 or less are obtainable. Over 90% of unwanted slimes can be eliminated from the underflow. Less fresh water is required, compared with classifiers, and higher slime content in feed slurry can be accepted. Smaller fluid volume must be handled. The required degree of desliming can be obtained in one piece of equipment without reduction of slurry rate or appreciable loss of desired solids. (10 references).—K. E. J.

FUEL—PREPARATION, PROPERTIES, AND USES

Mineral Constituents of Coal. R. L. Brown. R. L. Caldwell, and F. Fereday. (*Fuel*, 1952, **31**, July, 261–273). To find an accurate and simplified formula for the estimation of mineral matter, some 1400 analyses carried out by the King, Maries and Crossley (K.M.C.) method were studied; the ash, total sulphur, and CO_2 in mineral matter were chosen as the basis. It is shown that the equation mineral content $= 1{\cdot}06$ ash $+ 0{\cdot}53$ sulphur $+ 0{\cdot}74\ CO_2 - 0{\cdot}32$ differs very little from the K.M.C. formula for all areas except Scotland. In view of certain peculiarities observed (notably in Warwickshire), it is considered that the chemical and geological issues disclosed by the work should be examined in greater detail.—B. G. B.

The Mineral Matter in Coal and Its Relation to Coal Preparation Problems. A. Grounds and A. M. Wandless. (*J. Inst. Fuel*, 1952, **25**, July, 170–177). The authors give figures to show how changed conditions have led to the output of higher ash coal, with more dirt and fines. The influence of the distribution of mineral matter in raw coal on cleaning operations is discussed with particular reference to pyritic sulphur. The methods available for coal cleaning are outlined and discussed, with special mention of the production of coals for carbonization and steam raising. An account is given of the National Coal Board's construction programme for coal cleaning plant.—D. L. C. P.

Considerations on the Effect of Ash and Clinker in the Iron and Steel Industry. N. H. Turner. (*J. Inst. Fuel*, 1952, **25**, July, 187–188). Although the accurate isolation or assessment of the effects of ash and clinker on the various processes of iron and steelmaking is difficult, some approximate figures are derived for the effect of ash on blast-furnace, gas-producer, and locomotive fuel costs. The reduction of carbon available for smelting ores resulting from an increase in ash in coke of 1%, is approximately 30 lb., which, at today's prices, corresponds to 1*s.* 4*d.*/ton of coke used. If the ash content of a gas-producer coal increases from 5% to 10%, the extra cost involved may be 4·6*d.*/ton of initial coal. Special considerations apply to ash in the fuel beds of shunting locomotives.

Ash and Atmospheric Pollution. A. Fitton. (*J. Inst. Fuel*, 1952, **25**, July, 178–181). The dust emission caused by the consumption of various fuels is accounted for, and the size distribution of fly-ash is described. Methods of sampling and measurement of the dust content of gases, and the means of controlling the nuisance are outlined.—D. L. C. P.

Origin and Nature of Ash; Sampling and Analysis. L. J. Edgcombe and A. B. Manning. (*J. Inst. Fuel*, 1952, **25**, July, 166–170). After reviewing the above subjects, the authors consider the fusion temperatures of ash samples, their relation to chemical composition, and their utility in predicting the clinkering properties of a coal.—D. L. C. P.

Oil Additive Developed to Relieve Boiler Slagging. (*Blast Furn. Steel Plant*, 1952, **40**, Aug., 938–940). Addition of finely powdered alumina or dolomite to the oil fuel resulted in the dense hard deposit normally produced changing to a fairly soft ash. Results of tests on the pilot and field scales are given. The additive is used in an amount equivalent to the quantity of ash in the oil.—B. G. B.

Fuel, Heat and Power Auditing. L. Clegg and J. P. Walters. (*J. Inst. Fuel*, 1952, **25**, July, 136–145). The authors describe the work of the mobile testing units of the Fuel Efficiency Branch of the Ministry of Fuel and Power, and give detailed examples. This advisory service has carried out surveys on sheet-metal works, engineering works, and steelworks. Every industrial concern should 'audit' its fuel and power. The work has been of real service in promoting fuel economy, and impressing managements that they can effect considerable savings. The savings proved to be attainable have varied from 3·6 to 56%, the overall weighted average being 20·8%. The service includes a survey, testing of the plant, and recommendations.

Design and Construction of a High-Speed Camera and Its Application to Certain Combustion Problems. A. H. Howland and M. J. G. Wilson. (*Fuel*, 1952, **31**, July, 274–287). A description is given of a high-speed Schlieren camera and the associated spark light source capable of taking photographs up to a speed of 10,000 frames/sec. Some preliminary results are given of the application of the camera to the study of two combustion phenomena, namely, the oscillation of the inner cone of a 'roaring' bunsen burner flame, and the explosive combustion occurring in tunnel burners.—B. G. B.

Physics of Fuel Bed Combustion. M. W. Thring. (*Fuel*, 1952, **31**, July, 355–364). An investigation was undertaken to see how far the observed reaction rates in fuel beds could be predicted from the assumption that they are predominantly controlled by diffusion-mass transfer between gas and particles. It was found that the reaction hypothesis that speeds are governed purely by physical considerations does not apply to the reaction $CO_2 + C \rightarrow 2CO$, which occurs after all the oxygen is consumed.—B. G. B.

Flame Radiation Research. (*Eng. Boiler House Rev.*, 1952, **67**, Aug., 232–234). The work and results to date, of the international flame radiation research project which is investigating radiation from luminous flames is outlined. The influence of variables on oil fuel flames, as found in the performance trials, is summarized.—D. L. C. P.

International Committee for the Study of Flame Radiation: Study, on a Model, of Conditions of Mixing of Fuel and Air in the Furnace at Ijmuiden. M. P. Newby and J. D. Tyler. (*Chaleur et Ind.*, 1952, **33**, July, 203–208). The model laws governing the systems studied are explained. The experimental method with a $\frac{1}{10}$-scale model is outlined and the results are interpreted. The effects of the use of steam or air for atomization, and the quantity of excess air on the length of flame are shown.—T. E. D.

The Work of the International Committee for the Study of Flame Radiation. J. Dumas. (*Génie Civil*, 1952, **129**, Aug. 1, 289–292). The administrative organization of the project and details of the experimental plant, built at Ijmuiden, Holland, are described. The experimental furnace, 7 m. long, 2 m. wide and 2 m. high, was sufficiently large for conditions to approach those in industrial plant. Trials included the study of liquid and gaseous fuels from the point of view of combustion mechanism and flame radiation. Artificial luminosity was produced by injecting oil or tar into the fuel. The effects of fuel/air ratio, oxygen enrichment, and atomization were studied. Some of the results are given, and the instrumentation of the furnace is outlined.—T. E. D.

Luminous Flame Radiation: Trials at the Royal Netherlands Steelworks. (*Iron Steel*, 1952, **25**, July, 339–340). The object of the international flame radiation work carried out at the Royal Netherlands Steelworks is outlined, and a summary of the results obtained to date is given.—G. F.

Improved Heat Transfer in Waste-Heat Boilers. R. Doležal. (*Engineering*, 1952, **174**, July 25, 103–104). A method of improving heat transfer in waste-heat boilers is described and the example cited is a boiler utilizing the exhaust gases of internal-combustion engines working with blast-furnace gas. The rate of heat transfer was increased by inserting a thin-walled tube in the boiler tube.—M. D. J. B.

Considerations on the Efficiency of Heat Exchangers and Their Characteristic Coefficient *X*. J. Szczeniowski. (*Chaleur et Ind.*, 1952, **33**, July, 209–212). A dimensionless term X is proposed as a means of characterizing heat exchangers. Two particular types, the counter current and the parallel flow, are dealt with here, but the term X is also applicable to regenerators and to exchangers functioning with variable flows.—T. E. D.

Graphical Determination of C.V. of Mixed Gases. C. M. Wearing. (*Gas World*, 1952, **136**, Aug. 2, 291). The accompanying diagram provides a rapid graphical method of obtaining the calorific value of a mixture of two gases, the volume and calorific value of each being known.—T. E. D.

Xanthates in Coal Flotation. R. M. Horsley, H. El-Sinbawy, and H. G. Smith. (*Fuel*, 1952, **31**, July, 302–311). Contact-angle experiments are described. These demonstrate that pure alkaline xanthates are not collectors for coal, but that the commercial products or pure xanthates in the presence of oxidizing agents have a collecting action. This is due to the formation of dixanthogen.—B. G. B.

Carbonizing Properties: Chilton Coal from Lorado No. 5 Mine, Lorado, Logan County, W. Va. J. D. Davis, D. A. Reynolds, D. E. Wolfson, W. H. Ode, and B. W. Naugle. (*U.S. Bur. Mines Bulletin* 500, 1951).

Laboratory Method for Determining the Yield and Quality of the Chemical Products of Coking. V. N. Novikov and N. A. Gruzdeva. (*Zavodskaya Laboratoriya*, 1950, No. 3, 307–314). [In Russian]. A method is described which has enabled reliable estimates of the quality and yield of by-products in full-scale coking to be obtained in the laboratory. The coking is carried out in an electrically heated retort. Detailed comparison of full-scale data, with laboratory figures for yield of tar, crude benzol, ammonia, and gas, shows that similarity is obtained with modern practice employing coking times of 14–14¼ hr.—S. L.

Automatic Apparatus for Studying the Softening Process of Coal During Coking. N. S. Gryaznov and V. M. Zamkovaya. (*Zavodskaya Laboratoriya*, 1950, No. 3, 301–307). [In Russian]. An apparatus is described which automatically records the change in the state of aggregation of coal on heating. The method is based on measuring the friction between the coal and a moving steel surface, and it enables the transformations undergone by coal before becoming plastic to be noted, and a relative evaluation to be made of the fluidity of the plastic mass. Softening diagrams, obtained at temperatures below 520° C., are shown for a bituminous and a coking coal, and for some coal mixtures.—S. K.

Method for Determining Shrinkage During the Coking of Coal. A. E. Bresler. (*Zavodskaya Laboratoriya*, 1950, No. 3, 291–297). [In Russian]. The results of laboratory-scale dilatometric studies on the coking process are presented and discussed. The sample of semi-coke, prepared by heating coal in a steel cylinder to 410–500° C., was held between the flat bottom of a quartz tube and a quartz disc connected to an indicator. The extent of shrinkage and the temperature at which rapid shrinkage started during heating, were found to depend on the type of coal or coal blend, the temperature of the semi-coke, and the rate of heating in the dilatometer. A theory of crack formation in coke is developed.—S. K.

Further Studies of Coking Pressure. (*Brit. Coke Res. Assoc. Tech. Papers*, 1952, No. 5, June). Earlier work concerning the pressures developed by British coals during carbonization is extended by further examination of coal blends and blends containing coke breeze. The influence of rate of heating of the charge and the effect of variation of bulk density, either by alteration of moisture content or coal size, were studied. The following conclusions have emerged: (*a*) Coals with more than 25% volatile matter set up relatively small coking pressures at a bulk density up to 52 lb./cu. ft. (dry) with a few exceptions; (*b*) a coal or blend with a maximum wall pressure of less than 2 lb./sq. in. when carbonized at a bulk density of 52 lb./cu. ft. is unlikely to cause damage to a top-charged coke oven of normal height; and (*c*) it is unwise to rely entirely on low average bulk density to ensure freedom from pressure effects.—J. C. B.

Coking Coal in Australia. H. R. Brown and H. Berry. (*Colliery Guardian*, 1952, **185**, Aug. 21, 221–224). The chemical characteristics and coking properties of coal from some New South Wales seams are discussed. The differences between these coals and those of Europe and America are emphasized, since they do not fit into any of the accepted classifications. Low sulphur and high ash contents are prevalent, and normal washing processes seem difficult to apply.—T. E. D.

Rational Adaptation of Pre-Distillation on Ordinary Coal and Lignite-Fed Gas Producers. P. Roussey. (*Silicates Indust.*, 1952, **17**, Apr., 127–128). The development of a gas-distilling retort is described. It is mounted above the charge, on the producer, and receives a mixture consisting of producer and injected fuel gases. Instead of the conventional gas exit

temperature of about 550° C., an exit temperature of about 130° C. is thus obtained at the top of the retort, where most of the volatile components of the coal leave in gaseous form having a calorific value of 1850–2000. The coke is gasified in the usual manner, and the gaseous products are lead away from the producer near the base of the added retort, at a temperature of about 450° C. The calorific value of this fraction is about 1200. The advantages arising from the use of the retort are discussed.—P. F.

Developing the Use of Coke-Oven Gas in the Open-Hearth Sparrows Point Plant of Bethlehem Steel Company. J. H. Kelley. (*Blast Furn. Steel Plant*, 1952, **40**, July, 773–778). A practical method for burning high percentages of coke-oven gas in the open-hearth furnace has been developed, and is described. Higher checker temperatures can be obtained owing to the lower alkali checker deposits with coke-oven gas. The relation between heat time, preheat, and checker deposits for different fuels is important. Desulphurized coke-oven gas, supplied at the right pressure and used properly with a small amount of tar, gives an ideal open-hearth fuel.—B. G. B.

Water-in-Tar Emulsions. S. C. Porter. (*Gas World*, 1952, **135**, May 31, 592–593). The dispersion in which tar is the continuous phase and water the disperse phase is discussed. The study of the viscosity–water relationship and experiments to reduce emulsification are described. Large-scale tests are mentioned and emulsification mechanisms are suggested.

Present Trends in the Construction of Coke-Oven Gas Treatment Plant. W. Boulin. (*Chaleur et Ind.*, 1952, **33**, June, 155–170). A general survey is made of treatment procedures and plant layout. Numerous illustrations are included. The use of special materials and control mechanisms, and their effect on design and reduction of cost are discussed.—T. E. D.

Metallurgical Coke. I. Definition and Properties. F. Pintado Fe and J. R. Garcia-Conde. (*Inst. Nacional del Carbon, Bol. Informativo*, 1952, No. 5, Sept., 5–15). [In Spanish]. This is the first of a series of articles dealing with the work of the Spanish National Coal Institute on the problem of the preparation of mixtures for the manufacture of metallurgical coke from Spanish coals. Details are given of the washability and chemical properties of some Asturian coals and their physical properties.—R. S.

Reactivity of Cokes. H. L. Weisz and A. A. Orning. (*Fuel*, 1952, **31**, July, 288–301). Reactivity indices based on self-heating rates were determined for 122 cokes in air and 92 cokes in oxygen. Quantitative relations have been found between dry-ash-free volatile matter content and reactivity indices. These show a dominant influence of the chemical nature of the solid as measured by volatile content, which in turn is determined primarily by the maximum temperatures of carbonization. A study of low-temperature cokes reheated to 600–800° C. showed them to be somewhat more reactive than those originally carbonized at the corresponding temperatures. The effect of pore surface distribution was significant, but small compared with that of the nature of the solid.—B. G. B.

The Reactivity of Coke, Especially to Steam. G. A. Brender á Brandis and J. Felsbourg. (*Gas World*, 1952, **135**, June 28, 689–690). An apparatus for passing steam at a known rate over a column of hot coke is described and illustrated. The quantities of undecomposed water and water gas are used to measure the reactivity of coke at 1000° C.—T. E. D.

The Production and Utilisation of Metallurgical Coke. J. P. Graham. (*Metallurgia*, 1952, **46**, Aug., 74–78, 82). A general review is made of the coking industry in Great Britain and methods of producing metallurgical coke. Developments in modern coke-oven plant are discussed, including blending equipment. The necessity to conserve reserves of best coking coal by blending with lower-rank coals is stressed. Of the total of 16·1 million tons of coke produced in 1951, 64·4% was used in blast-furnaces. The utilization of coke in blast-furnaces is examined. It is improbable that any single set of universally acceptable criteria for blast-furnace-coke quality could be established.—B. G. B.

Thermal Break-Down of Coke. G. V. Speranskaya. (*Zavodskaya Laboratoriya*, 1950, No. 3, 297–301). [In Russian]. Experiments carried out with a view to explaining the differences in the behaviour of various cokes in the blast-furnace and devising better methods of testing blast-furnace coke are described. Drum-test results from a sample of a given coke were compared with those of a sample of the same coke after heating at 1550° C. in a 3-phase furnace and cooling in an inert atmosphere.—S. K.

The Suitability of Coke for Use in a Blast-Furnace, from the Point of View of Testing Methods. F. Byrtus. (*Hutnik* (Katowice), 1952, **19**, 7–8, 253–260). [In Polish]. The desirable properties of blast-furnace coke are outlined. A survey of methods of determining the chemical, physical, and mechanical properties of coke is given. The advisability of performing tests in works laboratories and the applicability of the results to full-scale furnace operation is discussed. (23 references).—V. G.

On Industrial Testing of Coke Reactivity. S. Traustel. (*Metall*, 1952, **6**, June, 298–302). The author discusses various methods for measuring the reactivity of coke.

A Study of Tests for the Evaluation of Coke. R. W. Campbell. (Amer. Iron Steel Inst.: *Blast Furn. Steel Plant*, 1952, **40**, June, 643–650; July, 779–786, 800). Several formulæ for the evaluation of blast-furnace coke are discussed. Final analysis of these formulæ indicates that variations in 11 plants caused deviations within the scope of any one of the suggested methods. This was especially true when an attempt was made to correlate blast-furnace performance of the different plants. Seven factors (moisture, volatile matter, ash, sulphur, screen index, tumbler test, and bulk density) are required to evaluate a coke, and plants are requested to determine these factors for one year.—B. G. B.

The Utilization of Coke Breeze. A. R. Myhill. (*Gas Times*, 1952, **72**, Aug. 8, 161–167). About 15% of the coke produced may be classed as breeze. The factors affecting this proportion are discussed. The designs of producers and boilers to utilize coke breeze are outlined.—T. E. D.

Gasification by the Moving Burden Technique. J. W. R. Rayner. (*J. Inst. Fuel*, 1952, **25**, Mar., 50–55). The author describes the development of this process by Imperial Chemical Industries, Ltd. who have had a pilot plant in operation since 1949. The method treats raw coal, in fluidized form, with steam and air in different vessels. On a full scale, the process would manufacture water-gas and by-product steam. Capital and running cost estimates show that it would compete with the conventional process.—D. L. C. P.

Heat-Transfer Coefficients for Industrial Gases. F. W. Lohrisch. (*J. Appl. Chem.*, 1952, **2**, Aug., 464–469). The author has prepared charts for the rapid determination of heat-transfer coefficients and for the presentation of new data based on recent experimental figures for the thermal conductivity of single gases and gaseous mixtures. These charts are applicable to the gases commonly used in industry.—R. A. R.

The Contribution of Gas to Scottish Industry. A. Buinowski. (*Indust. Gas*, 1952, **16**, Oct., 26, 28; *Gas World*, 1952, **136**, Sept. 20, *Industrial Gas Supplement*, 38–43; Oct. 18, 60–63). Recent gas installations in Glasgow are surveyed. They include gas-heated galvanizing baths, annealing furnaces for forged steel rolls and steel sheets, an infra-red paint-drying tunnel, a salt-bath furnace for the skin-annealing of turbine blades, and flame-hardening equipment. A course for the training of personnel for the industry is outlined, and the centralizing of information concerning the production and utilization of gas in the area is recommended.—T. E. D.

The Selection and Design of Gas Holders. R. H. Busbridge. (*Gas World*, 1952, **135**, June 21, 668–669). This is a précis of a paper presented to the 5th International Gas Conference, Brussels, June 17, 1952. Particular reference is made to spirally guided gas holders.—T. E. D.

TEMPERATURE MEASUREMENT AND CONTROL

The Extension of the International Temperature Scale below the Oxygen Point. H. van Dijk. (*N.P.L. Symposium on Recent Developments and Techniques in the Maintenance of Standards*, May, 1951, 51–58: H.M. Stationery Office 1952). The suitability of using the boiling point of hydrogen (20·39° K.) as a low-temperature primary standard, and the use of calibrated platinum resistance thermometers for the measurement of temperature below −183° C. are discussed.

Improvements in the Realization of the International Temperature Scale over the Range −182·97° C. to 630·5° C. C. R. Barber. (*N.P.L. Symposium on Recent Developments and Techniques in the Maintenance of Standards*, May, 1951, 58–62: H.M. Stationery Office, 1952). The work described involves new designs of platinum resistance thermometer, resistance measuring bridge, and improvements in the realization of the basic fixed points (ice, steam, sulphur, and oxygen).—B. G. B.

International Committee for the Study of Flame Radiation—Aspiration Pyrometers. I. M. D. Halliday. (*Chaleur et Ind.*,

1952, **33,** June, 171–176). Designs of aspiration pyrometers used in works trials are shown, and their accuracies are compared. On the basis of the results, a new design has been proposed, and this is illustrated.—T. E. D.

Closer Temperature Differentials in Bimetallic Thermostats. P. R. Lee. (*Product Eng.*, 1952, **23,** Apr., 179–181). A new bimetallic element consists of a rectangular-shaped piece having two longitudinal cut-out slots ; crimping of the two outer legs gives an inherent snap action. A spread of only two degrees between on and off is claimed and there is a life expectancy of one million operations.—A. M. F.

REFRACTORY MATERIALS

Refractories, and Their Raw Materials. L. Bor. (*Mine Quarry Eng.*, 1952, **18,** July, 227–230). The raw materials, manufacture, composition, properties, and uses of the whole range of refractory materials are described. Britain has abundant raw materials for the more common refractories of silica, fireclay, and semi-silica, but is not so well placed for certain ' special ' refractories.—D. L. C. P.

Use of Roasted Clay in the Manufacture of Firebrick. H. F. West and J. H. Veale. (*Bull. Amer. Ceram. Soc.*, 1952, **31,** June, 209–212). Production may be increased and quality maintained, without putting in additional kilns, by the introduction of one third roasted clay into the brick mix. The roasted clay heated to 1500° F. was found to be superior to brick grog, which is commonly used. The paper describes a simple laboratory oxidation test for clay which readily shows its burning behaviour.—E. C. S.

Use of Halloyzite from Michalovce for Refractory Bricks. O. Janák. (*Hutnické Listy*, 1952, **7,** 5, 242–244). [In Czech]. Details are given of the use, for the manufacture of refractory bricks, of the low-grade material (halloyzite), found in Eastern Slovakia, containing about twice the amount of water of crystallization as kaolinite.—P. F.

Magnesia from Sea Water. W. C. Gilpin and N. Heasman. (*Refract. J.*, 1952, **28,** July, 302–307). The history of the production of magnesia from sea water is briefly traced. The process was introduced into this country in 1936. It depends upon the reaction of soluble magnesium salts with a base to form insoluble magnesium hydroxide. The base is usually calcium hydroxide which may be conveniently provided by dolomite. The dolomite is first calcined, then slaked, and added to sea water, when the lime is converted to the relatively soluble hydroxide which subsequently precipitates magnesium hydroxide and passes into solution as a mixture of soluble calcium salts. The magnesia from the calcined dolomite remains unchanged, apart from some hydration, and settles with the magnesia derived from the sea water. Sea water contains magnesium sulphate and chloride in solution in amount equivalent to 2·15 g. MgO per litre. Details of the necessary pretreatment of the dolomite and sea water are given.—E. C. S.

The Selection of Aggregates for Refractory Concrete. T. A. Jones. (*Eng. Boiler House Rev.*, 1952, **67,** June, 171–172). The author details the fine and coarse aggregates which should be added to aluminous cement, to make refractory concrete for various purposes. Types and sizes of material are specified. Aggregates mentioned range from normal alumina refractory (for use at 1050–1200° C.), through chrome and chrome/magnesia to fused alumina, which may be used in concretes at up to 1750° C.—D. L. C. P.

Fused Stabilized Zirconia and Refractories. O. J. Whittemore, jun., and D. W. Marshall. (*J. Amer. Ceram. Soc.*, 1952, **35,** Apr., 85–89). Production of fused stabilized zirconia directly from ores in an electric arc fusion furnace is described. By this method, stabilized zirconia containing as little as 0·19% SiO_2 has been made in one furnace from an ore containing 33% SiO_2. Various properties of refractories made from fused stabilized zirconia are listed. Uses include linings for furnaces operating at up to 2500° C.—E. C. S.

A Note on Fused Stabilized Zirconia: A Modern High-Temperature Refractory. N. C. Jones. (*Refract. J.*, 1952, **28,** May, 214–216, 218). Zirconia is now produced from raw ores directly in grain form at a consumer cost of about 3*s.* 6*d*/lb. The significant properties of fused stabilized zirconia are : (1) Highest melting point of all commercial refractories. (2) Low volatility at high temperatures. (3) Lower thermal conductivity than any other commercial refractory. (4) Good thermal-shock resistance. (5) High resistance to oxidizing or moderately reducing furnace atmospheres without volatilization. (6) Low electrical resistivity at high temperatures. (7) Low reactivity, even at high temperatures. The established uses of fused stabilized zirconia refractories include : (1) Furnace linings in ceramic kilns at temperatures above 1700° C., metal melting furnaces (for steel, platinum, refractory alloys, etc.) and gas-synthesis furnaces. (2) Electric-furnace heating elements. (3) Liners for jet- and rocket-motor tubes.—E. C. S.

Magnesite Refractories. (*Ceramics*, 1952, **4,** June, 160–166). The raw materials are listed and the extraction of magnesia from sea water is outlined. The calcination of these raw materials, and the manufacture, properties, and applications of magnesite bricks are described.—E. C. S.

Carblox Limited—New Tunnel Kiln. (*Ceramics*, 1952, **4,** Aug., 31–32). The new tunnel kiln recently put into service at the Loxley Works of Carblox Ltd. has a total output of 100–140 tons per week. It will be used for the production of all forms of carbon refractories.—E. C. S.

A Review of Methods for Determining Particle Size Distribution of Ceramic Raw Materials. R. S. Lamar. (*Bull. Amer. Ceram. Soc.*, 1952, **31,** Aug., 283–288).

Basic Refractories. W. F. Ford, and J. R. Rait. (*West of Scotland Iron Steel Inst.*, Nov. 1951, Advance Copy). Present knowledge of the fundamental chemistry of basic refractories, and their service performance, is reviewed. It is shown that the constitutions of forsterite, magnesite, dolomite, and low-lime chrome–magnesite bricks can be determined. Knowledge of the constitutions of high-lime chrome refractories is incomplete, owing to the complexities induced by oxidation processes. The relationships of constitution and liquid formation are indicated, and specifically it is shown that a reduction of the silica content of sea-water magnesite is desirable. Evidence is presented that the mechanism of wear in service is by shelling, produced by flux absorption and the effects of spalling and bursting expansion. Modern trends in reinforcing basic refractories are summarized.—P. C. P.

Corrosion of Refractory Materials. H. Towers. (Deutsche keramische Gesellschaft : *Blast Furn. Steel Plant*, 1952, **40,** Aug., 921–925, 927 ; Sept., 1054–1060). A review is made of some of the more important contributions to this field of refractory knowledge published in the period 1940–50. Investigations concerning both fundamental research and the performance of refractories under service conditions are discussed. (66 references).—B. G. B.

Flow Characteristics of Fire-Clay Refractories at High Temperatures. P. G. Herold and C. Knusden. (*J. Amer. Ceram. Soc.*, 1952, **35,** Sept., 220–225). Several bricks of intermediate duty, high duty, and super-duty quality made by three manufacturers were tested in the load equipment. The test brick reached 1400° C. in 3 hr., was soaked at this temperature for 30 min., and then pressure was applied at the rate of 3½ lb./sq. in./min. Thus a pressure of 100 lb./sq. in. was applied in 30 min. The effects of Seger cone number, porosity, and lamination cracks on the flow characteristics are described. The increasing-load test is more rapid than the constant-load test for determining flow characteristics.

Improved Design of Apparatus for Measuring Thermal Conductivity of Refractories and Insulation at High Temperatures. V. J. Duplin, jun. and E. S. Fitzsimmons. (*J. Amer. Ceram. Soc.*, 1952, **35,** Sept., 226–229). Apparatus for measuring the thermal conductivity of refractories at high temperature has been improved at the Babcock and Wilcox Co., Alliance, Ohio. The accuracy of furnace temperature control is better and the operating procedure is more simple.—E. C. S.

Experimental Refractory Bodies of High-Melting Nitrides, Carbides, and Uranium Dioxide. P. Chiotti. (*J. Amer. Ceram. Soc.*, 1952, **35,** May, 123–130). Preparation of the nitrides and carbides of several metals and of refractory bodies from these materials is described. Reasonably strong and dense bodies can be prepared from these materials and from UO_2. Evidence showing the tendency of Be_3N_2, TaN, and ThN toward instability at high temperatures is presented.

The Electron Microscope. A. E. Williams. (*Ceramics*, 1952, **4,** June, 177–183). Some typical instruments and their use in mineral examination are described, and electron micrographs of magnesium oxide, alumina, and carbonyl iron are reproduced.—E. C. S.

Thermal Analysis and Its Application to the Identification of Ceramic Materials. (*Ceramics*, 1952, **4,** Aug. 10–16). The

article deals with the principles and application of the method. The necessary apparatus is briefly described and among other things, the evaluation of mixtures, identification, quantitative determinations, effect of particle size, and double differential thermal analysis are discussed.—E. C. S.

Thermodynamics in Ceramics. W. D. Kingery and J. F. Wygant. (*Bull. Amer. Ceram. Soc.*, 1952, **31**, May, 165–168 ; June, 213–217 ; July, 251–255). In Part I the concepts of energy and heat content are considered. Part II covers the concepts of entropy, free energy, and equilibrium, and the applications of these concepts in ceramic processes are also discussed. Part III deals with the prediction, on the basis of thermodynamic calculations, of the stability of ceramic materials under the processes of (1) dissociation, (2) reaction, (3) vaporization, and (4) oxidation-reduction.—E. C. S.

A Laboratory Furnace with Hydraulically Positioned Hot Zone. H. I. Sephton. (*Amer. Ceram. Soc. Bull.*, 1952, Sept., 322–323). A high-temperature rapid-loading furnace for studying small specimens is described. Temperatures up to 1500° C. can be obtained, and reducing, neutral, or oxidizing atmospheres can be used. It was designed for the examination of metal–ceramic mixtures at high temperatures.

Effect of Carbon Monoxide on Fireclay Refractories of Polish Production. F. Nadachowski. (*Prace Instytutu Metalurgii*, 1952, **4**, 2, 111–126). [In Polish]. The action of CO on five different types of Polish refractory brick was investigated. CO was passed over a sample for 200 hr. at 500° C. The samples were classified. Iron-bearing minerals were extracted from crushed samples and their catalysing effects on the carbon deposition reaction were compared.—V. G.

Mullite–Carborundum and Corundum–Carborundum Refractories. P. P. Budnikov and V. I. Khramova. (*Doklady Akademii Nauk S.S.S.R.*, 1952, **84**, 2, 325–328). [In Russian]. The preparation and properties of refractories based on mullite, carborundum, and corundum, with various additions of Chasov Jarski clay as a binder, are described.—V. G.

Investigation of the System MgO–CaO–TiO_2–SiO_2 Communication. II.—Silica-Containing Systems. A. S. Berezhnoi. (*Ogneupory*, 1950, **15**, 10, 446–453). On the basis of data from the literature and from the author's experiments, the ternary systems CaO–TiO_2–SiO_2 and MgO–TiO_2–SiO_2 are discussed and a tretahedral diagram of the CaO–MgO–TiO_2–SiO_2 system was constructed. To determine the regions of refractory and non-refractory compositions in this system, the refractory properties of numerous compositions were investigated and the location of the region of non-refractory compositions outlined.—V. G.

Ceramics, Refractories and Cements. J. White. (*Soc. Chem. Ind., Reports on the Progress of Applied Chemistry*, 1951, **36**, 353–373). The physicochemical aspects of ceramic materials are surveyed with respect to recent advances in the concept of the ionic structure and other properties of liquid silicate melts. The supply position of clays and other raw materials is outlined, and new work on enamels and glazes is mentioned. The properties of basic open-hearth roofs are outlined, and the development and properties of some special refractories are listed. Finally, some improvements in analytical and physical measurements are given. (150 references).

Ceramics Shield Stainless for Jets. R. G. Hicks. (*Machinist*, 1952, **96**, Sept. 6, 1377–1378). Since the U.S. National Bureau of Standards released the first of a new series of ceramic coatings for commercial application, the Stewart-Warner Corporation has experimented with methods of applying several coatings, particularly in jet-engine components. Metal life at jet heats has been doubled. Intergranular corrosion of some alloys at 1600 to 2100° F., has been reduced. The coating thickness should be 0·001 to 0·003 in.—E. C. S.

The Processes of Coating Refractory Materials and Cements by Pneumatic Projection. (*Usine Nouvelle*, 1952, **8**, Sept. 18, 29–30). This convenient and rapid method of relining cupolas is illustrated. The materials used for giving a satisfactory acid coating are listed. The same process for applying cement is also described.—T. E. D.

Ceramic Coatings. (*Aircraft Prod.*, 1952, **14**, Sept., 305–306). An outline of the Solaramic process is given. Thermal shock resistance and mechanical properties of the coatings are surveyed. Coatings as thin as 0·001 in. give satisfactory protection in many cases.—T. E. D.

Steel Foundry Refractories. R. Groves. (*Refract. J.*, 1952, **28**, May, 209–213). The uses of the three main types of bricks (fireclay, silica, and magnesite) in the steel casting industry are listed. Firebricks for cupolas, steel ladle and converter refractories, open-hearth melting, and plumbago crucibles are discussed.—E. C. S.

Problems in Buying Refractories. D. Wragg. (*Gas Times*, 1952, **72**, Sept. 5, 294, 299–302 ; *Ceramics*, 1952, **4**, July, 230–235 ; Aug., 26–30). The article includes sections on choice of supplier, price fixing and 'back-door' methods, standards of performance and variation in quality, buyer's storage problems, and the status of the customer in business.—E. C. S.

BLAST-FURNACE PRACTICE AND PRODUCTION OF PIG IRON

Possibilities of Development in the Production of Iron. R. Durrer. (*United Nations Economic Commision for Europe, General, E/ECE/Steel* 68, July, 1952, 5–12). The methods in use today for the manufacture of iron are reviewed. The metallurgical advantages of the oxygen-enriched low-shaft furnace and the electric low-shaft furnace are discussed.

Developments in the Iron and Steel Industry in Canada. P. E. Cavanagh. (*United Nations Economic Commission for Europe, General, E/ECE/Steel*/68, July, 1952, 13–14). The development of the iron ore deposits will more than double the production of iron ore in Canada in the next year or two. The inauguration of electric smelting furnaces to perform the selective reduction of iron in ilmenite to yield liquid iron (with lower carbon content than pig iron) and a useful titanium-bearing slag are discussed. The production of sponge iron in a tunnel kiln and the desulphurization of steel with magnesium are mentioned.—B. G. B.

Let's Take a New Look at Hydrogen as a Reducing Agent. C. R. Hayward. (*Eng. Min. J.*, 1952, **153**, Jan., 85–87). Hydrogen can be produced commercially by cracking natural gas, the steam–iron process, or electrolysis. It is used for extraction of nickel, tungsten, and chromium, and in some applications is better used in the nascent form from calcium hydride. Details are given of small- and pilot-scale trials on continuous reduction of pure iron oxides. Sintered magnetite concentrates were most suitable, and advantages can be expected in the reduction of titaniferous iron ores. Other recent applications include production of carbon-free nickel steel.

The Part Played by Hydrogen in the Blast Furnace and Its Consequences. J. G. Platon. (*Iron Coal Trades Rev.*, 1952, **165**, Aug. 15, 371–374). The author discusses the possibilities of injecting fuel, such as fuel oil or pulverized coal, into the blast-furnace and the part played by hydrogen in the reactions. It is shown that injection above the ordinary tuyere level has the best possibilities, and that this will provide a range of fuels whose consumption is of known economic importance and a marked improvement in the distribution of heat.—G. F.

New Concepts in Blast-Furnace Operation. J. G. Platon. (*Iron Coal Trades Rev.*, 1952, **165**, Aug. 22, 430–432). The author discusses new concepts in the field of blast-furnace practice, and compares the potentialities of the low-shaft furnace with those of the standard type of furnace. He concludes that any undistilled fuel may be used in all blast-furnaces by burning it in tuyeres above the normal tuyeres ; and that oxygen enrichment of the blast up to 40% may be applied, provided that two or more sets of tuyeres are used and the blast temperature is reduced.—G. F.

International Research on the Low-Shaft Furnace. H. Malcor. (*Rev. Univ. Min.*, 1952, 9th series, **8**, Oct., 393–400). After reviewing the merits of the low-shaft blast-furnace for the manufacture of iron, an illustrated description of such a furnace and ancillary plant which has been designed and built as a result of international collaboration, is given. The furnace is oval in horizontal cross-section (3 × 1·2 m.) and rectangular in vertical section (5 m. high above the 8 tuyeres). It is rated to produce 60–100 tons of iron/day from low-grade ores and solid fuels, and is expected to be in operation in 1953.—B. G. B.

Ore Reduction : Low-Shafting Smelting in India. R. A. MacGregor. (*Iron Steel*, 1952, **25**, Aug., 375–376). The author describes a pilot low-shaft ore-smelting furnace of the Duffield type which is nearing completion in Calcutta, and discusses the principles of its operation. The low-shaft furnace permits an appreciably higher CO_2/CO ratio than in high-shaft furnaces, and it is felt that low-grade ores can be worked more advantageously in the Duffield furnace.—G. F.

The Relationship between Carbon Deposition and Reducibility. J. M. McLeod. (*J. West of Scotland Iron Steel Inst.*, 1949–50, **57,** 242–253). Carbon deposition and reducibility of iron ores and sinters have been investigated under conditions similar to those in the blast-furnace. The carbon deposition range for some ores and sinters has been determined. The variation in the amount of deposited carbon with varying CO/CO_2 ratios is recorded. Carbon deposition is at a maximum with easily reduced ores or sinters.—P. C. P.

Sulphur in Metallurgical Operations. G. Grenier. (*Rev. Tech. Luxembourg*, 1952, **44,** Apr.–June, 65–81). Desulphurization processes occurring in the blast-furnace are reviewed. The mechanism and practice of desulphurization by sodium carbonate, powdered chalk, dolomite linings, and calcium carbide are discussed. Desulphurization reactions occurring in the mixer, and open-hearth, Bessemer converter, and electric furnace practices are reviewed. The influence of sulphur on the properties of steel (including the cracking of ingots, corrosion of steel, and mechanical properties) is described. (43 references).—B. G. B.

Technical Progress in Blast-Furnace Plants and Practice during the Last Ten Years. A. Ofiok. (*Hutnik* (Katowice), 1952, **19,** 7–8, 242–252). [In Polish]. A survey of developments in blast-furnace plants and operation is given. The following items are mentioned : Furnace profiles ; the relation of output to the volume ; burden preparation ; ore sintering and pelletizing ; charging ; separate smelting of fine and lump ores ; acid process ; treatment of iron outside the blast-furnace ; blast-furnace coke ; refractory materials ; operation at high pressure ; use of oxygen ; low-shaft furnace ; and blast-furnace repairs. (53 references).—V. G.

The Dependence of Daily Output of Foundry Pig Iron on Mean Silicon Content. A. Geras. (*Hutnik* (Katowice), 1952, **19,** 6, 206–211). [In Polish]. On the basis of observations made on a blast-furnace with a hearth 9 ft. 10 in. in dia. producing foundry iron during the period 1947–49, an attempt was made to correlate the daily output with the silicon content of the iron and the wind volume, expressed in r.p.m. of a reciprocating blower.—V. G.

Blast Furnace Charging: Automatic Burden Distribution Installed at Park Gate. (*Iron Steel*, 1952, **25,** July, 309–312 ; Aug., 353–357). At the blast-furnace plant of the Park Gate Iron and Steel Co. Ltd., the materials handling plant, charging equipment, and furnace tops have been modified from manual to mechanical handling with automatic controls. The operation of the new plant and the influence of these changes on the chemical constituents and physical dimensions of the charge, the sufficiency of supplies, and burden distribution in the furnace, are discussed.—G. F.

Co-operative Research in Iron Making. K. E. Jermy. (*Metallurgia*, 1952, **46,** Aug., 83–86). By fundamental work on furnace reactions and ore constitution, coupled with works and pilot-scale trials on iron-making processes, the Iron Making Division of B.I.S.R.A. is making considerable progress towards a more complete understanding of blast-furnace operation. Among research problems undertaken by the Division are the treatment of fine iron ores and the desulphurization of liquid iron outside the blast-furnace.—B. G. B.

The Smelting of Iron Ore in Electric Furnaces. Comparison of the Mechanical Characteristics of Cast Iron Manufactured in Electric Arc Furnaces and in Cupolas. M. Barbero and D. Fortino. (*Met. Ital.*, 1952, **44,** Aug.–Sept., 308–318). The authors examine the principal characteristics of cast iron smelted in an electric arc furnace and compare these with an iron of similar composition made in a cupola. The results are based on direct observation of a series of tests as well as on the published results of other authorities. Whilst electric furnaces have hitherto been considered an excellent method of producing cast irons of special composition which cannot be easily made in cupolas, and have been used in duplex processes with cupolas, especially to produce malleable iron, they have rarely been used for making ordinary grey iron. (26 references).—M. D. J. B.

TREATMENT AND USE OF SLAG

Some Chemical Properties of Slags. G. M. Willis and F. L. Hennessy. (*Proc. Australasian Inst. Min. Met.*, 1950, Sept.–Dec., 265–275). The authors develop the view that it is incorrect to consider molten slags as consisting of molecules of free and combined oxides. The chemical potentials of the components are proposed as a measure of free or combined oxide, and their changes with composition have been found in the systems $FeO–SiO_2$ and $Na_2O–SiO_2$. The change of chemical potential with composition resembles that found for liquids containing molecular compounds, and accounts for the success of the molecular treatment.—D. L. C. P.

Microscopic Determination of the Percentage of Glass in Blast-Furnace Slags. Enrica Padilla. (*Silicates Indust.*, 1952, **17,** May, 163–168). Reflection and transmission micrographs of slag, taken with ordinary and polarized light are shown, and their suitability for the determination of glass content is discussed. HCl was used for etching.—P. F.

PRODUCTION OF STEEL

A Semi-Integrated Steel Producer Views the Steel Industry. W. M. Akin. (Amer. Iron Steel Inst.: *Indust. Heating*, 1952, **19,** July, 1241–1248). The problems of large integrated steel companies are contrasted with those of the small producers. The possibility of developing large departments and manufacturing unprofitable items are among the problems considered. Plant location and availability of scrap, pig iron, and fuel are also dealt with.—B. G. B.

Blast-Furnace and Steel-Melting Plant at Shotton. (*Engineering*, 1952, 174, Aug. 15, 215–216). **Steel Works Developments at Shotton.** (*Engineer*, 1952, **194,** Aug. 1, 155–156). The developments described consist of the installation of two batteries of 44 coke ovens each, a blast-furnace with a hearth 27 ft. in dia. and 16 tuyeres, ore handling plant, sinter plant, and a new melting shop with eight 150-ton open-hearth furnaces.—R. A. R.

Technical Progress in German Iron and Steel. H. Schenck. (*United Nations Economic Commission for Europe, General, E/ECE/Steel/68*, July, 1952, 33–37 ; *Iron Coal Trades Rev.*, 1952, **165,** Sept. 5, 539–540). By burning an admixture of lime on the sinter bed and increasing the pressure of the draught, the sinter capacity has been raised from 18–24 to 38 tons/sq. m./hr. The optimum lime content is 4%. The manufacture of pig-iron in low-shaft furnaces is discussed. The use of oxygen-enriched blast has improved the qualities of basic-Bessemer steel. Successful results have been obtained in the open-hearth furnace by replacing chrome–magnesite with delomite bricks. The utilization of oxygen in many branches of the German iron and steel industry is being increased.—B. G. B.

Trends in Iron and Steelmaking Processes (with particular Reference to Sweden). B. Kalling. (*United Nations Economic Commission for Europe, General, E/ECE/Steel/68*, July, 1952, 15–18). A general survey is made of important new methods of iron and steel production, as well as of development in the methods previously used, which have been evolved during the last 10 to 15 years.—B. G. B.

Technical Research Trends in the French Iron and Steel Industry. H. Malcor. (*United Nations Economic Commission for Europe, General, E/ECE/ Steel/68*, July, 1952, 21–32). **Research Trends in the French Iron and Steel Industry.** H. Malcor. (*Iron Coal Trades Rev.*, 1952, **165,** Aug. 29, 471–475). The main characteristics of the French iron and steel industry are first reviewed. Advances have recently been made in the utilization of Lorraine coals for coke-making. The utilization of fine ore, beneficiation of Lorraine ore, and direct reduction processes are discussed. Advances in blast-furnace operation are to be expected from the development of effective and economical processes for the desiliconization and desulphurization of the iron while still liquid. Research on the basic-Bessemer process is being continued and a number of advances in the practice have been made.—B. G. B.

Fundamentals of Ferrous Metallurgy. A. A. Bates. (*Amer. Soc. Met.* 1952). This publication contains a course of eight lectures on the following subjects : (1) Metal production statistics ; (2) steelmaking ; (3) the open-hearth ; (4) ingots, solidification, crystallization ; (5) structure and properties of crystals ; (6) the iron–carbon equilibrium diagrams and the principles of steel treating ; (7) fundamentals of ferrous metallurgy ; and (8) complex steels and their treatment.—R. A. R.

Steel Mill Maintenance, Organization, and Administration. E. F. Donatic. (*Blast Furn. Steel Plant.*, 1952, **40,** Sept., 1039–1045). A detailed examination of steelworks maintenance organization and administration is made. Unit and central maintenance organizations are described, and examples of maintenance schedules at Kaiser Steel Company, Fontana, Calif., are given.—R. A. R.

Characteristics and Applications of Capped and Rimmed Steels. H. H. Smith. (*Wire and Wire Products*, 1952, **27**, Sept., 874–877). Methods of producing capped and rimmed steels are described. Procedures developed to comply with welding wire requirements are explained, and the behaviour of capped and rimmed steel wires in cold heading, chain making and electro-plating, is dealt with.—J. G. W.

Steel " Quality "—What It Is and How to Get It. H. W. McQuaid. (*Metal Progress*, 1952, **62**, Aug., 104–108, 164). With enough iron oxide and manganese in the molten steel to form the iron oxide and manganese sulphide inclusions (which separate as large globules) the sulphur content can be as high as 0·30% without causing hot shortness, bad surface, or difficulty in heat-treatment. Various deoxidation treatments and the advantages of electric melting to obtain low sulphur are discussed. The suitability of sponge iron (produced by reducing ore with hydrogen or natural gas) as a substitute for scrap is reviewed. The author considers that the steel mill which shows the best return for money invested is the semi-integrated mill with the most modern finishing facilities.

Some Aspects of the Manufacture of Sheet Steel for Vitreous Enamelling. E. Marks. (Inst. Vitreous Enamellers : *Sheet Metal Ind.*, 1952, **29**, July, 587–592). The author outlines the properties desirable in steel sheet intended for subsequent vitreous enamelling. The production of rimming steel in the open-hearth furnace and in the Bessemer converter is described, the latter process yielding steel particularly suitable for enamelling.—P. M. C.

Spectroscopic Control of the Thomas Converter. R. Breckpot and B. Juchniewicz. (*Mém. Centre National Recherches Mét.*, 1952, May, 5–14). The range 2100 Å. to 9000 Å. has been studied photographically. The present work employed an electron multiplier throughout, sometimes using one cell and sometimes using two simultaneously in different regions of the spectrum between 4000 Å. and 6000 Å. Variations in emission with time of blow were studied, flame spectra at various stages of blow are reported, and the effect of temperature is mentioned. Details are given of the electronic equipment used.—T. E. D.

The Influence of Calcium Oxide Additions on the Behaviour of Manganese and Silicon in Acid Steelmaking Process. I. A. Popov and B. V. Stark. (*Izvestiya Akademii Nauk, Otd. Tekh. Nauk*, 1950, No. 12, 1806–1814). The influence of variations in the lime content of slags upon the behaviour of manganese and silicon on the acid steelmaking process was investigated. The temperature dependence of the equilibrium constants of manganese and silicon for 4·5 and 9% of CaO in slag were deduced from the data obtained. The influence of lime upon the activity of ferrous oxide depends on the lime concentration in the acid slag, and is more pronounced at higher concentrations (about 7·8%).—V. G.

How to Use Lime in Steelworks to the Best Advantage. J. Trapl. (*Hutnik* (Prague), 1952, **2**, 7–8, 157–158). [In Czech]. The rational use of lime in melting is discussed. A. P. Strugoshnikov recommends additions of 6–8% of lime for open-hearth furnaces up to 100 tons, and 5–6% for larger furnaces.—P. F.

From the Experience of Stachanovites in Rapid Melting. J. Trapl. (*Hutnik* (Prague), 1952, **2**, 7–8, 152–154). [In Czech]. Rapid methods of melting steel, developed by Soviet Stachanovite teams, are discussed. A description is given of the progress of a rapid heat, particularly of the method of charging, and the application of mechanical equipment for the hot repair of open-hearth furnaces. Post-war methods of charging these furnaces are described and compared with pre-war practice. Ore and lime are charged so as to form several large masses embedded in scrap, so as to obtain better heat transfer. The heat input to ordinary and tilting open-hearth furnaces during the charging, melting, and refining periods is given.—P. F.

Bauxite as Addition for Open-Hearth Melting. J. Bečvář. (*Hutnik* (Prague), 1952, **2**, 7–8, 156–157). [In Czech]. Data are given on experimental work carried out with a 35-ton basic open-hearth furnace, in which, instead of the conventional CaF_2 additions, bauxite was used to increase slag fluidity. It was found that apart from not attacking the lining, as is the case with CaF_2, bauxite rapidly increases the fluidity of the slag, improves the heat transfer and boil, and reduces the consumption of magnesite.—P. F.

The History of Basic Steel Manufacture at Sydney, Nova Scotia. M. R. Campbell. (*Canad. Min. Met. Bull.*, 1952, **45**, June, 331–339: *Trans. Canad. Inst. Min. Met.*, 1952, **55**, 217–225). Fifty years of production by the Dominion Iron and Steel Co., Ltd., is outlined. The difficulties imposed by the use of Cape Breton coal and Wabana ore are mentioned. The 50-ton tilting open-hearth furnace of 1901 is shown. The Bessemer and duplex processes are mentioned and the active mixer practice and construction from 1912 to 1914 are outlined. The present operation of the 100-ton tilting open-hearth furnace plant is described.—T. E. D.

Oxygen in Steelmaking. D. J. Girardi and D. C. Hilty. (*J. Met.*, 1952, **4**, July, 703–708). A summary is given of the more important points raised at an Oxygen Symposium held by the Amer. Inst. of Min. and Met. Eng. where the importance of oxygen in steelmaking and its influence on the properties of the finished steel were discussed.—G. F.

Continuous Working with Producer Gas: Experience at the New Melting Shop of Round Oak Steel Works, Limited. E. Wood. (*Brit. Steelmaker*, 1952, **18**, July, 358–362). The new melting shop of the Round Oak Steel Works Ltd. is designed for working with producer gas. The author describes the initial difficulties which were experienced due to ' sooting ' in the gas main, and shows how they were overcome by regular compressed-air lancing over all parts of the main.

Desulphurizing in Basic Furnaces. T. Collén and S. Hollström. (*Jernkontorets Ann.*, 1952, **136**, 8, 317–374). [In Swedish]. After a statistical study of desulphurizing made on the basis of 700 open-hearth heats with producer gas, experiments in gas- and oil-fired open-hearth furnaces, and in electric furnaces, it was found that considerable quantities of sulphur may be taken up during the melting-down period, but this can be diminished by using liquid pig iron, compact scrap, and rapid melting down. Desulphurizing is dependent mainly upon slag basicity. In the trials, it increased directly as the slag basicity rose from 1·4 to 4. With regard to reducing slags, no relation was found between the ratio of sulphur in slag and steel, and the basicity.—G. G. K.

The All-Basic Open-Hearth Furnace: Technical Problems in Its Use in Industry. (*Iron Coal Trades Rev.*, 1952, **165**, July 11, 81–84). This article summarizes the proceedings of the Conference held by the West of Scotland Iron and Steel Institute, where problems in the design and operation of all-basic open-hearth furnaces were discussed. Special reference is made to the furnace at the Bilston works of Stewarts and Lloyds Ltd., and to experiments in progress at the Royal Netherlands Steelworks.—G. F.

Charge Control for a Basic Open-Hearth Furnace. V. H. Bridgewood and J. H. Kelly. (Amer. Inst. Min. Met. Eng.: *Blast Furn. Steel Plant*, 1952, **40**, Aug., 903–912). The dual influence of the oxygen equivalent of the metallic charge and the ore charged was investigated. The oxygen equivalent of the charge could be represented by the oxygen equivalent of the silicon in the iron. The ratio of the oxygen equivalent of the ore to the oxygen equivalent of the silicon in both hot and cold iron had a significant influence on the production rate and the carbon. The influence of the limestone on the basicity of the slag was also investigated. A statistical study of the results is given together with a description of a rapid method of determining slag basicity.—B. G. B.

The Open-Hearth Furnace in the American Iron and Steel Industry. F. Bartu. (*Met. Ital.*, 1952, **44**, July, Supplement 1–24). [In Italian]. In this comprehensive account of American practice, the author reviews new trends in steelmaking plant in the U.S.A. Information is given on dimensions and capacities of open-hearth furnaces together with descriptions of materials handling facilities, efficiencies, and fuel and refractories consumption.—M. D. J. B.

Viscosity Control of Fuel for Open Hearths. H. Krouse. (*Iron Steel Eng.*, 1952, **29**, July, 78–84). With a preset rate of flow to the burners, a viscosity change alters the flow rate due to the hydraulic resistance through the burner ports and piping. The change will also have an adverse effect on the atomization of the oil, and in turn on the combustion. Descriptions are given of different types of viscosimeter.

Natural-Gas-Fired Open-Hearth Furnaces. T. Corea and C. Stocchi. (*Met. Ital.*, 1952, **44**, July, 259–266). [In Italian]. The characteristics of natural gas combustion are examined in the light of modern furnace technique. Luminous and non-luminous flames are discussed and the advantages of natural gas fuels described. Details are given of tests carried out

during an experimental run of a 30-ton open-hearth furnace fired first with natural gas and then with oil supplemented by natural gas.—M. D. J. B.

Multiple Burners for Firing the Open-Hearth Furnace. W. H. Kahl. (*Iron Steel Eng.*, 1952, **29**, Aug., 55–57). Trials are described in which additional burners were built into an open-hearth furnace designed for 168 short tons which had increased in capacity to 205 short tons. The final successful arrangement had three burners at each end. The advantages achieved are discussed.—R. A. R.

Open-Hearth Furnace Controls. G. J. Gockstetter. (*Iron Steel Eng.*, 1952, **29**, Aug., 57–61). The automatic furnace control devices employed by the Republic Steel Corp. for the 200-ton tilting furnaces, fired with atomized oil and natural gas are described.—R. A. R.

Fuel Oil Atomization with Natural Gas. W. A. Peters. (*Iron Steel Eng.*, 1952, **29**, Aug., 61–62). Experience with the firing of large open-hearth furnaces with fuel oil atomized with high-pressure natural gas is reported.—R. A. R.

Control of Multi-Fuel Fired Open-Hearth Furnaces. R. G. Bryan. (*Iron Steel Eng.*, 1952, **29**, Aug., 62–63). Methods of controlling gas and oil fuel feeds to open-hearth furnaces, when the gas supply varies greatly and the oil is the make-up fuel, are described.—R. A. R.

Fuel-Air Ratio Controls for the Steel Industry. L. H. Coleman. (*Iron Steel Eng.*, 1952, **29**, Aug., 64). Electric and electric-pneumatic fuel–air ratio controllers, by the Leeds and Northrup Co., are very briefly described.—R. A. R.

BTU Control. S. H. Jones. (*Iron Steel Eng.*, 1952, **29**, Aug., 65–66). The essentials of control systems for dealing with the variables affecting the supply of heat to open-hearth furnaces are very briefly considered.—R. A. R.

Control Systems for Improving Open-Hearth Operation. J. R. Green. (*Iron Steel Eng.*, 1952, **29**, Aug., 66–68). Control systems for the measurement of tar, steam, and gas flows, and for summation of the different fuels are described.—R. A. R.

Modern Open-Hearth Control. H. Morton. (*Iron Steel Eng.*, 1952, **29**, Aug., 68–69). A system for the control of oil, tar, and steam for atomizing, for open-hearth furnace fuel supply, and its advantages are described.—R. A. R.

Forge Shop Installs Compact Steel Melting Plant. D. I. Brown. (*Iron Age*, 1952, **169**, June 12, 119–123). The new electric furnace shop of A. Finkl and Sons, Chicago, consisting of two 25-ton Lectromelt furnaces is described. Annual output is expected to be about 60,000 tons, of which 70% will be alloy steel. All raw materials except scrap are packaged or palletized. The charging crane is equipped with an automatic weighing device and analysis of the melt is determined quickly with a spectrograph.—A. M. F.

The Electric Furnace at the Forges de Clabecq. (*J. Four. Elect.*, 1952, **61**, Mar.–Apr., 55–56). A description is given of a new 16–20 ton electric furnace constructed by the Brown-Boveri Co.—B. G. B.

Oxidation and Linings in High-Frequency Furnaces. J. Mayer. (*Hutnik* (Prague), 1952, **2**, 7–8, 148). [In Czech]. A brief review of the composition and structure of H.F. furnace linings with notes on the rates of oxidation of carbon, chromium, and nickel in the melt is given.—P. F.

Automatic Direct Power Control for Electric Furnaces. F. E. Wittig. (*Z. Metallkunde*, 1952, **43**, May, 161–162). The construction and performance of an automatic power controller, rapid in response and sensitive to fluctuations of less than $\pm$ 1% of the nominal furnace temperature, are described. It embodies a Watt balance and a relay switch for starting two motors which operate the approximate and fine current controls respectively. The former control is effected by a sliding transformer tapping, and the fine control by changes in the effective length of a liquid resistor.—P. F.

Metallurgy in the Carbon-Rod Radiant-Resistor Furnace. W. Gödecke. (*Metal Treatment and Drop Forg.*, 1952, **19**, May, 197–202). This is an English translation of a paper which appeared in *Giesserei*, 1951, **38**, Apr. 19, 169–174, *see J. Iron Steel Inst.*, 1951, **169**, Nov., 288.

The Application of Thermodynamics in Fundamental Metallurgical Processes. A. Regner. (*Hutnické Listy*, 1952, **7**, 4, 178–181; 5, 234–242). [In Czech]. The fundamental thermodynamic principles are discussed from the point of view of chemical equilibria, particularly those involved in metallurgical processes, *i.e.*, the formation of metallic oxides and sulphides in relation to temperature. Ellingham's method is used to express graphically the free-energy changes in such reactions, and examples are given to show the method of employing these diagrams.—P. F.

X-Ray Determination of the Constituents in the Reduction Products of Oxides of Iron and Manganese. V. Montoro. (*Met. Ital.*, 1952, **44**, Aug.–Sept., 457–458). A brief description is given of the author's method of reproducing the different phases of the Fe–Mn–O system. The effects of different cooling rates on their X-ray characteristics are indicated. The author puts forward a quantitative method for determining the constituents of the reduction products of the mixed oxides of iron and manganese.—M. D. J. B.

Equilibria in Reduction in the CaO–Fe_2O_3 System. A. Burdese. [*Met. Ital.*, 1952, **44**, Aug.–Sept., 343–346). The author determines, for different temperatures, the reduction diagrams of sintered materials of a composition between monocalcic ferrite and ferric oxide. As shown by X-ray analysis, the sinters are a mixture of both these constituents. Study of the reduction process has enabled the author to establish the intermediate products and to define, for different temperatures, the simultaneous existence of phases in the ternary CaO–FeO–Fe_2 O_3 system. CaO–3FeO.Fe_2O_3 in the solid state, is stable between 680° and 1050° C. The only ternary solid, stable in this temperature range, is CaO.FeO. Fe_2O_3 (besides the solid solution of monocalcic ferrite in magnetite), which at high temperatures may contain an excess of calcium in solid solution. This phase can exist simultaneously in the liquid state with wüstite and tricalcium ferrite, whilst the tricalcium ferrite can exist simultaneously with two solid saturated solutions between the calcium and the wüstite.—M. D. J. B.

Reduction of Monocalcic Ferrite at Different Temperatures. V. Cirilli and A. Burdese. (*Met. Ital.* 1952, **44**, Aug.–Sept., 371–375). The reduction of monocalcic ferrite is studied in wide temperature ranges. The reducing agent was carbon monoxide, and, for temperatures below 800° C., hydrogen. Isothermal reduction diagrams are established and their accuracy is confirmed by X-ray analyses. The authors establish that the form of these diagrams is influenced, to a considerable degree, by temperature. Between 845 and 950° C., reduction takes place in the intermediate CaO.FeO. Fe_2O_3 and CaO.3FeO.Fe_2O_3 phases. Above 950° C., a new phase appears, consisting of a solid solution of monocalcic ferrite in magnetite, containing more oxygen than magnetite. Stability for the phase CaO.3FeO.Fe_2O_3 is between the temperatures of 680° and 1050° C., and between 845° and 680° C. the phase is reduced directly to iron. Below this temperature there is direct reduction of CaO.FeO.Fe_2O_3 to iron with simultaneous formation of tricalcium ferrite.

Silica/Iron-Oxide Systems. R. Schuhmann, jun. (*Amer. Iron Steel Inst. Regional Tech. Meetings*, 1951, 455–466). The author reviews the results of recent studies of equilibrium conditions in silica/iron-oxide systems, with particular reference to the action of iron oxides on silica bricks at steel-making temperatures. This action is quite sensitive to the oxygen potential in the atmosphere; increasing the oxygen potential raises the freezing point of iron silicate liquids and decreases the solubility of silica in them, thereby reducing the depth of liquid penetration into the brick and reducing the quantity of silica fluxed away by a given amount of iron oxide.—G. F.

Distribution of Manganese and Oxygen Between Molten Iron and FeO–MnO–SiO_2 Slags. H. B. Bell, A. B. Murad, and P. T. Carter. (*Trans. Amer. Inst. Min. Met. Eng.: J. Met.*, 1952, **4**, July, 718–722). The authors have determined the manganese equilibrium between molten iron and FeO–MnO–SiO_2 slags not saturated with silica, and from the results have estimated the activities of MnO and SiO_2 in the slag. Comparison of these activities with those obtained on FeO–SiO_2 slags, and those estimated on CaO–SiO_2 slags, shows them to be in agreement with the known cation–oxygen bond strengths for calcium, manganese, and iron. The data enable the manganese, silicon, and oxygen contents of molten iron in equilibrium with FeO–MnO–SiO_2 slags, containing less than 25% SiO_2, to be calculated with reasonable accuracy.—G. F.

Thermodynamics of Iron-Silicate Slags: Slags Saturated with Solid Silica. E. J. Michal and R. Schuhmann, jun. (*Trans. Amer. Inst. Min. Met. Eng.: J. Met.*, 1952, **4**, July, 723–728). By bubbling varying CO_2–CO mixtures through liquid iron-silicate slags and analyzing the ingoing and outgoing gases, the authors have determined the pCO_2/pCO ratios for the slags in equilibrium with solid silica in the temperature range 1250–

1350° C. From the data, the thermodynamic activities of iron and FeO have been calculated, and a new determination of the free energy of formation of magnetite has been made.

Continuous Casting of Steel in the United States. (*J. Four. Elect.*, 1952, **61**, Mar.–Apr. 51–53). Work carried out on a pilot plant at the Beaver Falls works of the Babcock and Wilcox Co. is reviewed. The results obtained have justified the construction of a further plant.—B. G. B.

Ingot Heat Conservation : Cooling of 8-ton Ingots between Teeming and Stripping. L. H. W. Savage and R. T. Fowler. (*J. Iron Steel Inst.*, 1953, 173, Feb., 119–128). [This issue].

Some Problems Relating to the Production and Control of Ingot Moulds in the U.S.S.R. J. Vrbenský. (*Hutnické Listy*, 1952, **7**, 5, 231–233). [In Czech]. Life, material, control, and classification of steelworks ingot moulds in the U.S.S.R. are discussed. Details of design and composition are given.

The Use in Foundries of Iron Cast in Pig-Casting Machines.—The Behaviour of Ingot Moulds Made of Machine-Cast and Sand-Bed Irons. (*Met. Ital.*, 1952, **44**, Aug.–Sept., 432–438). This paper examines the behaviour in a steelplant of 244 experimental ingot moulds made from two similar irons, one originally cast in a pig-casting machine and the second in a sand bed. Statistical analysis shows that there was no difference between the two groups of ingot moulds both as far as stripping characteristics and mould life are concerned.

The Relation between Durability of Refractories and Non-Metallic Inclusions in Steel. W. Szymborski. (*Hutnik* (Katowice), 1952, **19**, 6, 213-215). [In Polish]. The amounts and compositions of non-metallic inclusions in steel were investigated. Furnace, ladle, and casting-pit refractories can be responsible for some non-metallic inclusions, but can also remove inclusions formed during the deoxidation of steel by aluminium and ferrosilicon.—V. G.

PRODUCTION OF FERRO-ALLOYS

Chromium Minerals and the Electrothermic Manufacture of Chromium Iron Alloys. J. Dabalà. (*Met. Ital.*, 1952, **44**, Aug.–Sept., 376–390). After briefly describing the principal characteristics of chromium-bearing minerals, the author examines the deposits of the major chromium-producing countries. Tables are given of the average analyses of the different minerals and the annual production. The author also examines the physical properties of chromium, and its uses in the metallurgy of iron and steel, and more particularly in the manufacture of chromium-iron alloys. The most modern electrothermic methods for the production of chromium-bearing iron alloys are briefly noted.—M. D. J. B.

Manganese Extraction by Carbamate Solutions and the Chemistry of New Manganese–Ammonia Complexes. R. S. Dean. (*Min. Eng.*, 1952, **4**, Jan., 55–60). A new process for the extraction of manganese from low-grade oxide or carbonate ores (down to 7–8% Mn), not capable of mechanical concentration, is based on the discovery of aqueous manganese–ammonia complex solutions, permitting rapid extraction of manganous oxide. Ammonium carbamate is utilized. Addition of CO_2 produces manganese carbonate, from which the oxides or salts are easily prepared. Impurities are easily controlled. A commercial plant is being built to supply manganese salts, and eventually MnO for smelting. (10 references).—K. E. J.

Recovery of Manganese from Slag Heaps: American Experiments. F. J. Knight. (*Iron Coal Trades Rev.*, 1952, **165**, Aug. 22, 435–436). A description is given of American pilot-plant trials on the recovery of manganese from slag heaps. The slag is first treated in a blast-furnace to produce a metal with 12–15% Mn ; this is then blown in a special converter to produce a high-grade slag containing about 60% Mn, which is a suitable synthetic ore for producing ferromanganese. The process is found to be practicable but uneconomical.—G. F.

The Electrothermal Treatment of Minerals Containing Iron and Nickel from Lokrys (Greece). C. Ferrente. (*J. Four. Elect.*, 1951, **60**, Sept.–Oct., 115–117). The production of a nickel–iron alloy from a mineral containing 36% Fe and 2·38% Ni by reduction in an electric furnace is described. The production of ferronickel (22–28% Ni) by preferential reduction of the nickel oxides is also dealt with.—B. G. B.

Electrolytic Manganese Tests in Co-operation with Industry. F. Sillers, jun. (*U.S. Bur. Mines Rep. Invest. No.* 4861, 1952, May). An extensive series of tests was conducted by 45 firms in which electrolytic manganese produced by the Bureau of Mines from low-grade home ores was substituted for the normal grades of ferromanganese in the production of ferrous and non-ferrous metals and alloys and welding-rod coatings. The electrolytic manganese was found satisfactory, and, in the case of stainless steels, more so than normal ferromanganese due to its freedom from carbon and phosphorus.—B. G. B.

Electrometallurgy and Electrochemical Operations at the Rainham Works (England). (*J. Four. Elect.*, 1951, **60**, Sept.–Oct., 118–121). The type of work carried out at the Rainham factory of Murex Ltd., is described. The firm manufactures the metal, alloys, and chemical derivatives of tungsten, vanadium, molybdenum, and manganese, also metallic chromium and alloys, metallic titanium and tantalum, ferroniobium, and special alloys with cobalt, boron, nickel and iron.—B. G. B.

Investigation of Molten Ferrophosphorus Alloys by Electromotive Force Measurements. O. A. Esin, L. K. Gavrilov, and N. A. Vatolin. (*Doklady Akademii Nauk S.S.S.R.*, 1952, **85**, 1, 87–89). [In Russian].

FOUNDRY PRACTICE

Interesting Comparisons of Local and Overseas Foundry Practice. J. A. Preston. (*Australian Found. Trade J.*, 1952, **3**, Mar., 3, 5, 6 ; June, 15, 16). The author lists and briefly discusses eight advantages which he claims the British foundryman has over his Australian counterpart. The advantages are : Quality of raw materials ; enthusiasm for sand control ; materials handling and storage ; core-making ; recruitment of suitable labour ; consideration of orders before they reach the foundry ; costing ; and technical aids to increase productivity.—P. M. C.

New Methods in Grey Iron Foundries of the German Democratic Republic. (*Hutnik* (Prague), 1952, **2**, 7–8, 161–162). [In Czech]. Recent developments in binders for moulding materials are discussed. These include : (1) Replacing Portland cement additions by brown-coal dust obtained from electrostatic dust separators in electric power plants ; and (2) the use of ground cupola slag and water-glass. The economic aspects are analysed.—P. F.

Gray Iron Foundries. (*Economic Cooperation Administration, Technical Assistance Division*, Aug., 1951). A detailed survey of American grey iron foundry practice is presented. Over one million castings are produced every month and four out of every five tons of metal cast are of grey iron. Information is given concerning the operating efficiency, machinery and equipment, and production and quality control.—B. G. B.

Methods of Economizing in Foundry Coke. G. M. Kogan and B. M. Diemkov. (*Przeglad Odlewnictwa*, 1952, **2**, 7–8, 266). [In Polish]. Economy in the consumption of coke was achieved by screening it into three sizes : <10 mm., 10–30 mm., and >30 mm. The coke breeze was utilized in a cupola by charging it separately after every three to five charges of normal coke.—V. G.

Charge-Level Indicator for Cupolas. (*Foundry Trade J.*, 1952, **93**, Aug. 7, 167). A recent patent describes a charge-level indicating device consisting of two iron bricks in the side of the cupola, which are positioned so that a rise in the level causes a short circuit and lights up a signal lamp.—R. A. R.

Save by Briquetting Borings. (*Amer. Foundryman*, 1952, **21**, June, 40–41). This note describes the plant of Stockham Valves and Fittings Inc., Alabama, in which turnings are stored, dried, and pressed into 11-lb. briquettes. These are suitable for charging into cupolas.—E. T. L.

Oxygen in the Malleable Foundry. J. B. La Pota and L. H. de Wald. (*Amer. Foundryman*, 1952, **22**, July, 35–41). The author describes experiments to find the best use of oxygen enrichment in the foundry. The most progress is reported in fuel enrichment when heating a cold metal charge, for oxidation of certain elements, for improving cupola operation in the cupola/air-furnace duplexing process, and for use as a combustion agent in annealing. With pulverized coal fuel, the introduction of extra oxygen gives a hotter flame, faster melting, and a reduction of the fuel/metal ratio. Another advantage is the greater control of bath temperature. The oxygen is added to the air which blows the pulverized coal into the furnace.—E. T. L.

Automatic Devices Facilitate British Foundry Operations. V. Delport. (*Foundry*, 1952, **80**, July, 86–91). The author describes units employed by Ferranti Ltd. for automatically adding inoculant to cupola iron, and for measuring the moisture content of the moulding sand.—E. T. L.

Melting Control by Cupola Pyrometer. R. I. Taylor. (*Foundry Trade J.*, 1952, **93**, Aug. 28, 229–232). The author describes the use of a thermocouple to control the operation of a cupola. It is mounted at least 2 ft. below the top of the charge, with the sheath protruding about 4 in. beyond the lining ; at this point the working temperature is about 500° C. The interpretation of a temperature record is discussed, showing its practical importance in detecting bed deterioration before it becomes serious.—E. T. L.

The Influence of Additions of Sulphur and Tellurium During the Casting of Hardened Rolls. V. E. Karskij. (*Przeglad Odlewnictwa*, 1952, May, 165–168). [In Polish]. The production of high-quality cast-iron rolls is briefly discussed. The improvement of structure obtained by the addition of sulphur and tellurium is described.—V. G.

Classification of Graphite in Grey Iron. R. Krzeszewski. (*Przeglad Odlewnictwa*, 1952, **2**, 7–8, 249–259). [In Polish]. Existing classification of forms of graphite in grey iron and the difficulties encountered in classifying the graphite in a sample are outlined.—V. G.

Concerning the Graphitization of Iron. K. P. Bunin and I. V. Salli. (*Doklady Akademii Nauk* S.S.S.R., 1952, **83**, 6, 841–842). [In Russian]. The graphitization of white iron (C 4%, Mn 0·1%, Si 0·5%) during heat-treatment at 950° C. *in vacuo* was investigated. On the basis of experimental evidence it is stated that the controlling factor in the velocity of graphitization is the removal of the iron atoms with which the initiation and growth of graphite inclusions is connected.

Experimental Production of Nodular Iron. G. Kniagninin and W. Kowalik. (*Przeglad Odlewnictwa*, 1952, **2**, 7–8, 216–219). [In Polish]. Production of nodular iron on a laboratoy scale is described. Inoculation was made with a magnesium–nickel alloy.—V. G.

Guiding Principles for Conducting Trials before Starting Production of Spheroidal Iron on an Industrial Scale. J. Piaskowski. (*Przeglad Odlewnictwa*, 1952, June, 182–190). [In Polish]. The main kinds of spheroidal graphite iron, methods of production, and uses are briefly discussed. A description of the trials which a foundry must make before commencing the production of this iron on a large scale is given.—V. G.

Contribution on the Production of Cast-iron with Nodular Graphite. B. Marincek. (*Roll'schen Eisenwerke Mitt.*, 1951, **10**, June–Dec., 14–44). The author discusses the reactions which take place in molten cast iron, and experiments in the production of nodular cast iron by the addition of pure magnesium. The mechanical properties of the iron thus produced correspond to the known properties of nodular cast iron. The formation of nodular graphite and the differences in the forms of graphite in cast iron are explained in terms of the surface tension of molten cast iron. Experiments show that the surface tension of the melt is a function of the quantity of oxygen in solution. Thus, nodular graphite is formed in melts very low in oxygen.—E. C. S.

Versatile Core Boxes. R. H. Harwell and J. H. Schaum. (*Foundry*, 1952, **80**, May, 154–155, 342). A table is given of the dimensions of standard core boxes, inserts, and core prints, which simplifies core storage and reduces the number of core boxes needed in a jobbing foundry.—E. T. L.

Production of Ingot Moulds by Sandslinger in a Mechanized Foundry. J. R. Jones. (*Inst. British Foundrymen : Foundry Trade J.*, 1952, **93**. July 24, 101–105 ; July 31, 131–135). This is a description of the procedure at the Landore Works of Richard Thomas and Baldwins Ltd., for making moulds for steel castings of between 10 and 25 tons. The plant dealt with includes drying stoves, cupolas, sandslinger, patterns, and the processes of coremaking, stripping, and testing.

Core Maker Uses Ultramodern Controls. L. F. Miller. (*Iron Age*, 1952, **169**, 'May 15, 114–117). **Automatic Indexing Turntable Speeds Core Production** L. F. Miller. (*Foundry*, 1952, **80**, Apr., 112–113). An automatic machine for producing high-quality cores has been produced by the Osborn Manufacturing Co. It consists of a five-station turn-table co-ordinated by electric timers which control the operation of solenoid air valves actuating the various operations.—A.M.F.

Modern Trends in Molding Machines and Core Blowers. G. E. Miller. (*Foundry*, 1952, **80**, Mar., 102–105, 215, 216). Modern machines reduce physical effort and the dependence on individual skill, and improve productivity. The use of squeeze-type moulding machines has increased. The improvements in machines are due to greater squeeze pressures, better handling facilities, and the use of automatic or semi-automatic controls.—E. T. L.

Foundry Machines. C. Stieler. (*Z.V.d.I.*, 1952, **94**, July 1, 551–554). Machines exhibited at the 1952 Hanover Fair are described, and the recent trends in design shown by them are discussed.—J. G. W.

Making a Separate Oven for Drying Sand-Lined Ladles. C. C. Spencer. (*Amer. Foundryman*, 1952, **21**, May, 82). An oil-fired furnace for reducing the drying time from 10 to about 4 hr. is described—E. T. L.

Don't Overlook the Importance of Core Driers. W. A. White. (*Foundry*, 1952, **80**, May, 236–238). Practical hints are given on the design and fitting of core driers.—E. T. L.

Casting Steel Spokes in Large Iron Wheels. P. Dwyer. (*Foundry*, 1952, **80**, May, 291–292). This article is in the form of questions and answers on the technique of casting band-saw wheels 5 to 8 ft. in dia. with cast-iron rims and hubs and wrought-iron spokes. Special attention is given to the method of ensuring that the spoke ends are tightly gripped in the hub.—R. A. R.

Casting in Open Molds. P. Dwyer. (*Foundry*, 1951, **79**, Dec., 255–258 ; 1952, **80**, Jan., 143–144 ; Feb., 163–166). The author makes recommendations on casting in open moulds, either from the side or from a feeder leading into the base. The design of runners for casting rectangular and circular flat plates is also dealt with.—R. A. R.

Metal Moulds for Iron Castings. W. Chabowski. (*Przeglad Odlewnictwa*, 1952, **2**, 7–8, 220–222). [In Polish]. The production of metal moulds is discussed.—V. G.

Casting Molds for Steel Ingots. P. Dwyer. (*Foundry*, 1952, May, **80**, May, 192–194). The author describes the method of moulding employed by the Dominion Steel and Coal Corp. Inc. for making moulds for 77-ton ingots.—R. A. R.

Milling Cutters by the Casting Process. (*Railway Gaz.*, 1952, **97**, Aug., 241). The production of milling cutters by this process is briefly described. The cutters are manufactured from a high-speed steel which has chromium as the chief alloying element instead of tungsten or molybdenum.

Forty-Foot Furnace Installed for Pre-Heating Investment Casting Moulds. (*Indust. Heating*, 1952, **19**, June, 1040). A brief account is given of the double-end, five-zone furnace for the above purpose.—B. G. B.

The Use in Foundries of Iron Cast in Pig-Casting Machines.—The Manufacture of Spun Tubes from Machine-Cast and Sand-Bed Irons. (*Met. Ital.*, 1952, **44**, Aug.–Sept., 439–447). Some 7000 tubes of all diameters were made out of identical medium-phosphorus iron, except for the method of casting the pigs. The tubes were submitted to close statistical analysis which showed that the method of casting the pigs had no significance. The cupola irons obtained from melting down both types of pig were also submitted to chemical and mechanical tests, and revealed no differences in quality. Somewhat more uniform cupola casting temperatures were, however, obtained with the machine-cast irons.—M. D. J. B.

Casting Developments. A. Dunlop. (*Metal Ind.*, 1952, **81**, Sept. 5, 183–185 ; Sept. 12, 206–207). Four modern precision investment casting processes are described, and the relative merits and fields of application of each are discussed. The lost-wax process is most suitable for small intricate castings, whilst the 'Mercast' process, which uses expendable frozen mercury patterns, is capable of producing slightly larger castings with particularly complicated internal contours. The Shaw process makes use of non-expendable master patterns, is simpler than the previous two, and can produce larger castings. Shell moulding or the 'C' process is the simplest of all the four processes, and steel castings weighing up to 56 lb. may be produced with a finish and accuracy better than normal sand casting, but rather inferior to that obtained in the expendable pattern processes.—P. M. C.

The Shaw Process of Precision Casting—Methods Employed and Typical Applications. (*Machinery*, 1952, **81**, Oct. 2, 768–777). The Shaw process differs fundamentally from normal n vestment casting in that no wax is employed, and accurate moulds are produced directly from suitable masters or patterns. These moulds can be produced from the patterns in an average time of 3 min. each, and they may be ready for pouring in 1 hr.—E. C. S.

Current Status of the Shell Molding Process. R. W. Tindula. (*Foundry*, 1952, **80**, July, 201–210). After a review of patent developments, refractories and bonding materials, and the various stages of the above process, the author concludes that

the main advances have been in faster handling, quicker curing of the shell-mould, easier stripping by the use of better parting agents, and the extension of the process to more metals and larger castings.—E. T. L.

Foundrymen Discuss Shell Moulding and Ductile Iron. H. J. Roast. (*Metal Progress*, 1952, **62,** July, 93–95, 146–147). The work of two foundry conferences, one naval and one civil, is reviewed. At the former conference, ceramic moulding and the manufacture of propellers (usually from manganese bronze) were discussed. At the second conference, the shell moulding process was dealt with and recent improvements in the composition of the phenolic resin and in the design of patterns were reviewed. Details of the use of cerium to neutralize the harmful effects of some residual impurities in ductile iron were given.—B. G. B.

The Shell Molding Process. F. L. Church. (*Modern Metals*, 1952, **8,** Apr., 28–33). The Croning shell moulding process, in which lightweight moulds are made from phenolic resin and sand, is described in some detail. The advantages discussed include easier preparation and assembly, and the production of more accurate castings.—T. E. D.

Model Castings Developed for Huge Forging Press. (*Foundry* 1952, **80,** July, 98–99). A 75,000-ton closed-die forging press is being designed in the U.S.A., and, as part of the preliminary work, stress analyses are being made of model castings of the main cylinder holding rings.—E. T. L.

Costs Cut 30% by Investment Castings. (*Prec. Met. Mold.*, 1952, **10,** Aug., 30–31). Details are given of the production cost reductions achieved by substituting investment casting for the fitting of bar and plate stock in the manufacture of gun-sight parts.—D. H.

Investments for the Precision Casting Process. W. F. Davenport and S. Strott. (*Foundry*, 1952, **80,** July, 92–93. 192–198). This study of the feasibility of using materials which are more plentiful for investments in precision casting, indicates that low-priced foundry sands may be used as the refractory. Satisfactory results were obtained using binders such as phosphate salts, plaster, and alumina-base cement. Suspension agents, such as bentonite and tragacanth, should not be used in an investment because they hold water physically, thus preventing drying.—E. T. L.

The Trial and Development of Die Casting Dies. H. K. Barton. (*Machinery*, 1952, **80,** June 26, 1124–1132). The question of reducing the number of trial runs required for dies is considered.—E. C. S.

Internal Strains and Life of Centrifugal Moulds. H. Bühler. (*Métaux-Corrosion-Indust.*, 1952, **27,** Apr., 164–168). The distribution of internal strains in centrifugal moulds is illustrated by a series of graphs. The performance of a number of steels used for the manufacture of these moulds is discussed; a steel containing 0·25% C, 1·8% Cr, 0·2% Mo oil-tempered and reheated to 670° C. has given the best performance to date.—B. G. B.

Dynamic Method of Casting. H. Mastalerz. (*Przeglad Odlewnictwa*, 1952, **2,** 7–8, 233–239). [In Polish]. By dynamic casting is meant the shaking of the mould during solidification of the metal. Experiments were made in which the moulds were placed on a vibrator either during filling, or during solidification. The structure and mechanical properties of the castings were investigated. Some modification in feeding arrangement was found to be necessary. The possibilities of using this method on an industrial scale are discussed.—V. G.

Developments in Casting Technique. C. S. Darling. (*Mech. World*, 1952, **131,** May, 209). A brief description is given of sequential or dual-metal casting by the centrifugal process.

Job Foundry Tackles Shell Mold Production. G. P. Derby. (*Iron Age*, 1952, **169,** May 15, 109–113). A pilot-plant shell moulding machine of the Lynchburg Foundry Co., Va., is described. This is a four-station machine operating on a turntable supporting patterns at 90° intervals.—A. M. F.

Faster Hot Metal Handling Increases Foundry Capacity. W. M. Grimes. (*Foundry*, 1952, **80,** May, 209–210, 214). The experience of one American foundry is used to show that mechanization of hot metal handling (using an overhead tram-rail system) leads to a great increase in productivity.

Casting Brake Drums at the Budd Co. Foundry. J. H. Hall. (*Foundry*, 1952, **80,** June, 118–122, 194). The layout and equipment of this nighly mechanized American plant producing 4000 castings per 8-hr. shift are described.—E. T. L.

High Frequency Heating. A. E. Williams. (*Engineer*, 1952, **194,** Aug. 15, 215–219). The use of high-frequency heating methods in industry is rapidly expanding. Here, the use of the method is surveyed in its applications to the heating and melting of metals, the hardening of steel, soldering, gluing, drying, and in the plastics industry.—M. D. J. B.

Mechanized Production of Cast Iron Pipes. (*Machinery*, 1952, **81,** Aug. 21, 311–318). New conveyors and other equipment for casting rain-water and soil pipes at the Carron Company, Falkirk, are described. The pipes are cast in 6-ft. lengths and may range from $2\frac{1}{2}$ to 4 in. in dia., the latter size having a wall thickness of $\frac{5}{16}$ in. When working to full capacity, 4-in. pipes can be produced at the rate of 1000 per day with a total labour force of 56.—E. C. S.

Modernized Foundry Boosts Castings Output. R. H. Hermann. (*Foundry*, 1952, **80,** July, 100–105, 216, 218). The author describes the reorganization that has occurred at one of the foundries of the Dodge Manufacturing Corp., Mishawaka. This led to an increase of 50% in production. E. T. L.

Foundry Mechanization: A Survey of Modern Methods and Equipment. J. Bain. (*Iron Steel*, 1952, **25,** July, 329–332; Aug., 369–372). In this survey of modern mechanized foundry equipment, the author describes the different types of apparatus available and their suitability for particular applications. It is shown that more development work has been undertaken on moulding machines than on any other item of plant. Further progress depends largely on new ideas on sand preparation.—G. F.

Mechanized Foundry Layout. (*Mech. Handling*, 1952, **39,** Aug., 387–382). Details are given of the layout of the mechanized iron foundry at Triplex Foundry Ltd., Great Bridge, Staffs, where repetition castings (*e.g.*, firegrates and domestic cookers) are made. Several types of conveyor for molten metal, moulding materials, and moulds are described.

A New Foundry. K. Mallener and J. Stadler. (*Giesserei*, 1952, **94,** July 24, 362–366). Works studies have led the authors to the view that, under certain conditions, batch manufacture is preferable to continuous assembly-line in a foundry for small and medium castings. The layout and equipment of such a foundry are indicated.—J. G. W.

Rotary Melting Furnaces. (*Metal Ind.*, 1952, **81,** Aug. 1, 90, 91). A recently developed horizontal rotary melting furnace, by the Monometer Manufacturing Co. Ltd., is described and illustrated. Such furnaces may be fired by oil, gas, or pulverized coal, and can be used for the routine automatic production of steel, iron, copper, and aluminium. A typical 2-ton furnace, oil-fired, consumes 30 gal. of fuel per ton of steel, 18 gal./ton of copper, and 8 gal./ton of aluminium. Overall times for melts of the above metals are 120, 120, and 35 min. respectively.—P. M. C.

Blowholes in Castings. P. Dwyer. (*Foundry*, 1952, **80,** Apr., 211). A frequent cause of blowholes in castings is the presence of carbonates, such as particles of sea shells, in the moulding sand; these give off CO_2 when the temperature reaches 1470° F.—R. A. R.

Stresses in Castings. L. Amendt. (*Giesserei*, 1952, **39,** July 24, 372–373). Faults in casting technique, which give rise to residual stresses, are discussed.—J. G. W.

Sealing Porous Castings by Vacuum Impregnation. (*Machinery*, 1952, **80,** May 29, 959–960). The use of vacuum chamber and pump, supplied by the Pulsometer Engineering Co. Ltd., Reading, for impregnating castings with bakelite solution is described.—E. C. S.

Standardizing Casting Practice. A. S. Grot and L. H. Carr. (*Amer. Foundryman*, 1952, **21,** June, 42–48). The causes of variation in the quality of high-pressure valves, were investigated. Shrinkage caused 60% of all defects at a particular American company. Defects were recorded with an improved system, to indicate location and severity. A great improvement in quality resulted from applying directional solidification, and from the empirical comparison of different gating and heading practices.—E. T. L.

Statistical Method of Control in a Foundry. V. M. Dmitriew. (*Przeglad Odlewnictwa*, 1952, No. 5, 157–162). [In Polish]. The use of statistical methods for the control of production in a foundry is advocated. As an example, a description is given of an investigation made in a Russian foundry which resulted in considerable improvement in production. The rejects due to the low temperature of metal and faults in casting were cut

down by 85%, and simultaneously the cupola output increased by 27·6% and coke consumption was lowered by 6%.—V. G.

Sealing Metal with Metal. D. W. Holmes. (*Modern Metals*, 1952, **8**, Feb., 53–54). Tincher Products Co. of Sycamore, Illinois, have developed a process for impregnating porous castings, and so avoiding their rejection. Metallic oxides are employed as seals in a form which may be circulated over the casting at 180° F., and then a pressure of 400 lb./sq. in. is exerted for 5–30 min.—T. E. D.

Atmospheric Pollution. L. C. McCabe. (*Indust. Eng. Chem.*, 1952, **44**, Jun., 103A–106A). The reduction of dust to acceptable levels from grey-iron foundries may be achieved through conversion to electric, reverberatory, or rotary melting furnaces. With conventional cupolas, the high-temperature bag filter unit can be effective, but at high capital cost ; otherwise multi-stage cleaning must be adopted, using dry cyclone multitube separators, wet washers, or packed towers, and lastly, bag filters or electrostatic precipitators. Service results from several installations are quoted.—K. E. J.

The Industrial Hygiene Engineer Who Guards Factory Workers' Health. S. C. Rothmann. (*Amer. Foundryman*, 1952, **22**, Aug., 56–60). This article outlines the functions of the foundry safety officer.—E. T. L.

Silicosis in the Foundry Industry. A. C. Thomson. (*Australian Found. Trade J.*, 1952, **3**, June, 19). This is a very brief note on the distribution and seriousness of this disease. The work of B.I.S.R.A. is outlined.—P. M. C.

HEATING FURNACES AND SOAKING PITS

Electric Furnace Company Expands Research Facilities. C. L. West. (*Indust. Heating*, 1952, **19**, Aug., 1414–1432, 1536). **Value of Furnace Research Shown at Electric Furnace.** C. L. West. (*Steel Processing*, 1952, **38**, July, 344–350). The Electric Furnace Co., Ohio, operates a very well equipped research department which deals with any problem connected with furnace design and operation. The following units are described : A continuous gas-fired combined with electrically heated roller-hearth strip line for handling commercial widths of strip ; a gas-fired, forced circulation type bell furnace ; and several special atmosphere processing units.—P. M. C.

Some Cost-Saving Applications of Small High-Frequency Heaters. (*Machinist*, 1952, **96**, July 26, 1147–1150). The applications include the production of carbide tips and thermocouples, the hot forging of bolts, and the annealing of electric motor rotors and of pins for riveting.—E. C. S.

Hot Shipments Saving Months of Steel Processing. (*Australasian Eng.*, 1952, May 7, 105, 107). During a raging Canadian blizzard a red-hot steel ingot weighing 37 tons was shipped by rail a distance of 800 miles ; during this journey the temperature only dropped from 1800° F. to 1575° F. The ingot was placed in a cast iron box with a pre-moulded vermiculite lining. Several weeks, the time normally spent in slow cooling and eventual reheating, were saved between casting and forging.—P. M. C.

HEAT-TREATMENT AND HEAT-TREATMENT FURNACES

Planning in the Heat-Treatment Shop. B. Voženílek. (*Strojírenství*, 1952, **2**, No. 6, 263–269). [In Czech]. Questions of economy, labour productivity, and rationalization of methods and equipment for heat-treatment processes are considered. Details are given of equipment for continuous treating including carburizing, quenching, and stress-relieving.

Diffusion of Carbon and Nitrogen into Steel at High Temperatures. D. A. Prokoshkin and P. M. Arzhanyi. (Trudy Moskovskogo Inst. Stali im. I.V. Stalina, Symposium XXX, " Structure and Properties of Steel," *Metallurgizdat* (Moscow), 1951, 241–255). The influence of the principal factors such as temperature, concentration of salts in the bath, and holding time on the diffusion of carbon and nitrogen in low carbon and alloy steels during cyanide treatment was investigated. With an increase of temperature, the amount of carbon in the diffusion layer increased and that of nitrogen decreased. The maximum nitrogen content in the cyanide case was observed to be at about 860° C., the nitrogen being concentrated mainly in the outer zone. As the concentration of cyanide increased, the degree of saturation of the surface of steel with carbon and nitrogen also increased. In a bath containing calcium cyanamide the absorption of nitrogen was not great. The depth of diffusion of carbon and nitrogen increased with an increase of holding time. Metallographic, electron, and X-ray diffraction analyses of the microstructure of the cyanided surface of steel at 920–940° C. indicated the presence of a carbonitride phase with a cubic lattice. Simultaneous absorption of carbon and nitrogen by the steel at high temperatures improved the properties of steel, especially the fatigue strength, compared with the results obtained with a solid carburizing medium.—V. G.

Isothermal Heat-Treatment of Meehanite Metal. C. R. Austin. (*Metal Progress*, 1952, **62**, Aug., 109–112). Castings manufactured by the ' Meehanite ' method only are considered. In this process, the charge to be melted is computed to a predetermined liquid composition and the melt is then subjected to a suitable treatment to produce a correct constitution and microstructure in relation to the section of the casting to be poured. The equipment and procedure used for establishing the **S**-curve of such an iron is described in detail. The beginning and end of isothermal transformation, and the effect of different austenitizing temperatures were determined, and the effect of selective isothermal treatments on tensile properties was studied. Results are compared with those of spring steels ; hardnesses are comparable at the lower isothermal transformation temperature levels. It has also been established that an increase in the austenitizing temperature increases the stability of the austenite.—B. G. B.

Pick the Right Type of Metal for Flame-Hardening Meehanite Castings. C. R. Austin. (*Machinist*, 1952, **96**, Aug. 16, 1273–1277). Different types of Meehanite metal react differently to flame-hardening. The results of some tests which will help users to make the right choice for a particular application are presented.—E. C. S.

Factors Influencing Pack Carburising. E. Mitchell. (*Metallurgia*, 1952, **46**, Aug., 61–72). A series of tests to establish the effect of temperature and the amount and type of energizer, on the nature of the case obtained with both plain carbon and alloy case-hardening steels is described and the results are tabulated. The effect of dilution of the carburizing compound is discussed and suggestions are made for a compound which will prevent the formation of the heavy carbide networks associated with heavily alloyed case-hardening steels. The effects of moisture, density of the compound, and heating rate are also discussed.—B. G. B.

Flame Hardening Turret-Ring Ball Races. B. A. Schevo and Z. J. Fabrykowski. (*Welding J.*, 1952, **31**, Aug., 699–703). The fixture and procedure used for flame-hardening of turret rings in a vertical position are described.—U. E.

Kidde Boosts Cylinder Production with Automatic Heat-Treating Equipment. V. J. Hill. (*Indust. Heating*, 1952, **19**, Aug., 1390–1398). A continuous, automatically operated, controlled atmosphere furnace unit, which hardens and tempers steel cylinders, up to 850 cu. in. capacity, without forming scale, is described. The installation consists of a hardening furnace, oil quench, vapour degreaser, tempering furnace, cooling chamber, endothermic cracker, and exothermic generator. Scale-free surfaces are achieved by using an endothermic lithium gas in the hardening furnace for a neutral atmosphere or carbon restoration purposes, and an exothermic lithium atmosphere in the tempering furnace.—B. G. B.

Economies Effected by H.F. Induction Heating. (*Indian Eng.*, 1952, **129**, Jan., 40–41). A number of illustrated examples of the use of this technique for soldering, brazing, and hardening are given. The time for processing is reduced and semi-skilled labour can be used.—B. G. B.

High Frequency Hardening. D. W. Brown. (*Machinist*, 1952, **96**, Sept. 6, 1369–1376). The examples of induction hardening which are described show where high-frequency hardening with small equipment is economical. The process is used for rotary files, tappet adjusting screws, lathe collets, typewriter levers, fuel injectors, saw blades, car engine valves, machine taps, and windscreen wiper shafts.—E. C. S.

Induction Hardening of Machine-Tool Ways. G. W. Seulen and Alf. (*Schweissen u. Schneiden*, 1952, **4**, Sept., 332–334). The above process is described.—U. E.

Surface-Hardened Machine-Tool Ways. H. W. Grönegress. (*Schweissen u. Schneiden*, 1952, **4**, Sept., 328–331). The author discusses the application of flame-hardening to machine-tool ways.—U. E.

Axle Shaft Flanges Annealed in Liquid Bath Furnace. J. Kremer. (*Indust. Heating*, 1952, **19**, Aug, 1400–1404, 1536). The operation described consists of immersing only the outer portion of the flange of the shafts in a lead bath to

produce a more machinable condition, without reducing the torque transmitting power of the shaft itself. The flanges range from 4⅞ to 9⅝ in. in dia. and from $\frac{7}{16}$ to $\frac{11}{16}$ in. in thickness. Each bath, holding about 4000 lb. of lead, can deal with 1000 small shafts per day.—B. G. B.

Isothermal Annealing of Hypereutectoid Steels. M. Baj. (*Met. Ital.*, 1952, **44,** Aug.–Sept., 319–329). The problem of annealing hypereutectoid steels is examined. The usual methods of annealing are slow and unreliable. The author applies isothermal treatment to six typical hypereutectoid steels and establishes experimentally the optimum annealing conditions. The method suggested softens the steel, and takes much less time than the conventional methods. The practical difficulties of large-scale isothermal heat-treatment are examined and the practicability of extending the method to the industrial scale is considered. (10 references).

Annealing Large Calibre Steel Cartridge Cases. (*Indust. Heating*, 1952, **19,** July, 1194–1198, 1210). In the fabrication of these cartridge cases by the cold drawing process the material is annealed between draws to relieve the stresses produced. The processing and annealing cycles are described. The cases are annealed at 1250° F. for 20–30 min. in continuous, electrically heated, roller-hearth furnaces with a protective atmosphere of cracked gas.—B. G. B.

Continuous Annealing of Strip Steel at Dominion Foundries and Steel Limited. W. R. Weir. (*Amer. Iron Steel Inst. Regional Tech. Meetings*, 1950, 217–232). A description is given of the construction and operation of the continuous strip annealing plant at the Hamilton (Ontario) Works of the Dominion Foundries and Steel Ltd., which is designed to anneal cold strip up to 34 in. wide at speeds up to 300 ft./min. The economic and technical aspects of the process are compared with the normal batch-annealing method.—G. F.

Annealing for Narrow Strip Mills. J. L. Whitten. (*Iron Steel Eng.*, 1952, **29,** Aug., 84–90). This paper shows how extensively the narrow strip industry in the U.S.A. has adopted annealing in single-stack furnaces with high convection gas circulating systems, high heat inputs, alloy inner covers, and oil-sealed bases to eliminate the use of sand for seals.

Annealing Accelerated with Radiant Heat. C. A. Turner, jun. (*Steel*, 1952, **130,** Apr. 14, 106–111). The continuous high-speed annealing of strip, utilizing direct-fired radiant gas heating equipment, is described. Uniform temperature of the radiating burner cup surfaces is controllable from 1300–3100° F. by fuel-input regulation. With the strip moving at 1000 ft./min. the preheat to cooling cycle only occupies 90 sec. A washing stage is usually included in the line.—A. M. F.

Twenty-Five Years of Electric Furnace Manufacture. (*Metallurgia*, 1952, **45,** June, 303–304). The rotary drum annealing furnace, the duplex nitrider for aero-engine crankshafts and liners, and the malleable annealing equipment were all pioneered by Birlec Ltd. Among their heating applications are continuous-furnace copper brazing, continuous bright annealing, and gas carburizing. Gas-fired equipment, induction heat-treatment, and a moisture remover are among other developments reviewed.—B. G. B.

New Plant for Flame Hardening: Uses Town Gas and Has Automatic Temperature Control. (*Brit. Steelmaker*, 1952, **18,** Mar., 136–137). **Flame-Hardening by Oxy-Town Gas.** (*Coke Gas*, 1952, **14,** Apr., 144). **Flame Hardening.** (*Aircraft Prod.*, 1952, **14,** Apr., 144–146). A description is given of the Peddinghaus (Gevelsberg, Germany) system of oxy-town-gas flame hardening. The process allows the production of local hard surfaces on parts subject to wear, replacing the more complicated and costly processes of case-hardening and nitriding, and also permits the use of straight carbon steel in place of alloy steels. The machine is fitted with automatic temperature control.

Ipsen Atmosphere Furnace for Bright Heat-Treating. R. Krogh and E. J. Rupert. (*Metal Treating*, 1952, **3,** May–June, 2, 3). The design of a modern 250 lb./hr. unit is described and illustrated. It is available for gas or electric operation and is based on the principle of 'straight through' transfer of material. Three degrees of agitation of the quench tank are available.—P. M. C.

Production Problems—XVI: Quenching of Needle Wire. (*Iron Steel*, 1952, **25,** June, 297–298). A description is given of an investigation into the causes of cracking in quenched needle wires. Many of the cracks are found to be true quench cracks due to the use of brine as a quenching medium, and it is suggested that this treatment should be replaced by oil-quenching.—G. F.

Some Problems on Quenched Steels. III—On the Mechanism of Temper Hardening in Some Quenched Special Steels. K. Monma. (*Sci. Rep. Res. Inst. Tôhoku Univ.*, 1951, **3A.** Aug., 459–467). The mechanism of temper hardening in manganese steels and high-carbon chromium steel was investigated by means of hardness, dilatometric, and microscopic observations. The precipitation of carbide from retained austenite during tempering played an important rôle in hardening, independent of the Ar″ transformation.—J. G. W.

Determination of the Cooling Capacity of Quenching Baths. M. Pesante. (*Met. Ital.*, 1952, **44,** Apr., 145–152). [In Italian]. The author describes a new instrument for determining the cooling capacity of quenching baths. It makes use of electronic devices and plots the rate of cooling in degrees centigrade per second in relation to the temperature. Results obtained for baths of water, aqueous solutions, oils, salts, and low-melting-point metals are presented.—M. D. J. B.

How To Cool Oil-Quench Tanks. C. L. Ringquist. (*Machinist*, 1952, **96,** Oct. 4, 1614–1616). Good circulation of oil in heat-treating operations, where quenching is done continuously, gives an even bath temperature, which promotes consistent results in the metal treated. It also may keep oil below its flash point and eliminate evaporation of oil at high temperatures. Four typical cooling systems are outlined.

The Mechanism and Kinetics of the First Stage of Tempering. C. S. Roberts, B. L. Averbach, and M. Cohen. (*Amer. Soc. Met., Preprint No.* 11, 1952). This study was made on high-purity iron-carbon alloys, and on commercial steels; it involved X-ray and length measurements. The first stage of tempering proceeds by the growth of an aggregate of low-carbon martensite, and a hexagonal close-packed carbide, at the expense of the primary martensite. The carbide has the approximate composition of $Fe_{2\cdot4}C$. The third stage of tempering, involving the formation of cementite, generally begins before the completion of the first stage. The kinetics of the second stage are reported in an appendix. The results suggest that carbon diffusion in austenite is the controlling process.—E. T. L.

Methods of Reducing Wastage Due to the Brittleness of Annealed High-Speed Steel. A. A. Badaeva and E. I. Malinkina. (*Stanki i Instrument*, 1951, No. 2, 28). [In Russian]. Tempering for 2 hr. at 740° C. was found to reduce the brittleness of high-speed steel.—S. K.

FORGING, STAMPING, DRAWING, AND PRESSING

Design of Forging Press Die Bolsters. E. W. Mace. (*Steel Processing*, 1952, **38,** July, 335–339; Aug., 385–387). Bolster design for mechanical forging presses is discussed. The desirable features are outlined and the drawbacks of standard patterns are pointed out. Bolsters are usually suitable for one specific job, and frequent changing is necessary. A new design is here described which is more versatile. Brief details of its construction are given.—P. M. C.

Increasing Drop Forging Die Life. J. Mueller. (*Steel Processing*, 1951, **37,** Oct., 509, 510; **38,** Feb., 68–70, 101). (Continuation of a series of articles, see *J. Iron Steel Inst.*, 1952, **170,** Feb., 171). The design of rougher and finishing stations for closed die forging is discussed, and a die design for a ring forging is shown. Die lubrication and the wide diversity of views on this subject are dealt with. The use of graphited compounds and the effects of pigment content in lubricants are reviewed.—P. M. C.

What's New in Forging Equipment? J. C. McComb. (*Steel Processing*, 1952, **38,** Mar., 128–130; Apr. 175–179). A new pressure impact hammer being developed by Pneumatic Drop Hammer Co. is described, and the latest trends in gravity and steam drop hammer design are discussed. Recent designs of mechanical high-speed presses, upsetters, and forging rolls are described and illustrated.—P. M. C.

The Art of Anchor Forging. C. D. Linnenbank. (*Steel Processing*, 1952, **38,** Apr., 167–171, 205). This is an interesting short historical account of anchor forging and its development.—P. M. C.

Hollow Extruded Forgings Conserve Critical Materials. G. W. Motherwell. (*Machinist*, 1952, **96,** Oct. 11, 1649–1651). The making of long hollow parts by combining forging and extrusion, reduces machining operations and increases production rates. The method and tooling for making a part for an aircraft landing gear cylinder as a hollow extended forging are described.—E. C. S.

Cold Forming Stainless Steel Parts. K. Rose. (*Mat. Methods*, 1952, **36,** July, 101–116). Stainless steels can be fabricated by cold-forming methods quite readily if certain special considerations are kept in mind. The various stainless grades vary considerably in their forming characteristics, and the author discusses in detail the selection of the proper grade for a particular cold-forming operation, the cold-forming properties of the various grades, cold-forming methods, tool and die materials, and annealing procedures.—P. M. C.

A Simple Method for Measuring the Impact Energy of Steam Hammers. F. Drastik. (*Hutnik* (Prague), 1952, **2,** 7–8, 178–179). [In Czech]. A method, based on the deformation of metallic cylinders, of measuring the efficiency of the energy transferred by impact when using steam hammers, is described, and a chart for rapidly converting this deformation into efficiency of energy transfer is given.—P. F.

Manufacture of Forging Presses and Other Heavy Engineering Equipment: Influence of Modern Machine Tools and Welding on Design. J. G. Frith. (*Iron Coal Trades Rev.*,1952, **165,** July 11, 69–74 ; July 18, 137–142). After outlining the basic and detailed design of forging presses, the author describes the equipment necessary for manufacturing them and also refers to the wider application of such equipment for making other heavy steelworks and engineering plant. He then discusses the influence on press design of modern machine tools and of welding, and a comparison is made between cast and welded baseplates for a 2000-ton press. Reference is made to maintenance and to improvements in design and apparatus for controlling forging operations.—G. F.

Coining Controls Thickness and Location of Shell Flange. (*Machinist*, 1952, **96,** July 26, 1152–1154). In coining operations on shells, the metal should be confined so that plastic flow is induced only in the desired area.—E. C. S.

American Application of the Ugine-Séjournet Extrusion Process. (*Engineer*, 1952, **194,** Nov. 21, 680–683). **New Method Makes Stainless Extrusion Practical.** (*Steel*, 1952, **130,** June 2, 92–96). **Tough Alloy Steels Successfully Hot Extruded.** (*Iron Age*, 1952, **170,** July 3, 120–121). **New Tube Extrusion Process at Babcock & Wilcox Co.** (*Indust. Heating*, 1952, **19,** June, 998–1016). The cold extrusion process at the Beaver Falls works of Babcock and Wilcox Co. is described (see *J. Iron Steel Inst.*, 1952, **172,** Dec., 437).

Dies for Piercing Gas Traps for 3·5 in. Rockets. D. H. Smith. (*Machinery*, 1952, **81,** July 31, 187–195). An important component of the 3·5 in. anti-tank rocket is the ' trap ' which controls the escape of the propellant gases. The cadmium-plated steel traps, approximately $1\frac{3}{8}$ in. in dia. by $\frac{5}{32}$ in. thick, have 21 holes ranging from $\frac{7}{32}$ to $\frac{3}{8}$ in. in dia. The Oldsmobile Division of General Motors Corp. found that an improved product could be obtained with fewer operations and at higher production rates, by piercing instead of drilling the 21 holes required.—E. C. S.

The Design of Small Punches for Stamping. F. Strasser. (*Steel Processing*, 1952, **38,** Aug., 382–384). The author gives information about, and diagrams of, standard and special designs of small punches. The use of backing plates, factors to be remembered when punching small holes in heavy stock, and methods of avoiding the clogging of small slugs in the die are described.—P. M. C.

Specialty Die Designs for Stamping and Forming. L. F. Spencer. (*Steel Processing*, 1952, **38,** Mar., 121–127 ; Apr., 180–185, 190, 191, 194 ; May, 234–239, 257). The first instalment deals with the Marform rubber die process, which is described in detail. Its capabilities with respect to materials and their drawability are discussed. The Guérin process, which employs a rubber pad as the pressing medium, is described in Part 2, and some of its many applications in the sheet metal forming field are outlined and illustrated. The Sol-A-Die process, initially developed by the Solar Aircraft. Co., San Diego, is dealt with in Part 3. This is used when a limited number of complex sheet metal components are required, but where the numbers do not warrant expensive intermediate die design. A wax and cheesecloth impression of the final shape is made, and this pattern, being flexible, is then flattened out progressively to give patterns for intermediate dies which are simply cast in a zinc alloy or cast iron. (14 references).—P. M. C.

Compound Dies Blank, Pierce, and Form Multiple Parts. W. M. Stocker, jun. (*Machinist*, 1952, **96,** Sept. 6, 1382–1385). Glen Pfister has shown that high-speed-steel compound dies in high-speed presses are more practical than simple carbon steel dies in kick presses.—E. C. S.

Cost Reduction of Stampings by Cost Analysis Methods. J. M. Leake. (*Steel Processing*, 1952, **38,** Aug., 391–393, 399). The author discusses waste reduction in the stamping shop, and the necessary qualifications, character, and mental outlook of the ' cost reduction engineer'. A few of the many possibilities of cost reduction by savings in unexpected places are outlined.—P. M. C.

How to Hot-Form a Dimple. T. A. Dickinson. (*Steel Processing*, 1952, **38,** Apr., 172–174). Rivet holes in thin ferrous and non-ferrous sheets are usually dimpled when a perfectly smooth outer surface is required, as in aircraft body construction. Materials which have a tendency to work harden and crack may be successfully dimpled by applying heat through the dimpling dies. Methods and machines in use on this work at Northrop Aircraft Inc., are described and illustrated.—P. M. C.

Die Design for Metal Blanking. R. C. Berliner. (*Steel Processing*, 1952, **38,** July, 329–332). The author discusses three basic classes of blanking die ; temporary or quick-process types, and permanent dies of the progressive and compound types. Details and drawings of typical examples of each type are given.—P. M. C.

Feeders and Retrievers Aid Lamination Blanking. B. C. Brosheer, (*Machinist*, 1952, **96,** Aug. 2, 1204–1207). By supplying mechanical devices to load and unload presses, and to stack laminations, Allison Div., General Motors Corp., obtains more production of large laminations, minimizes fatigue, and improves safety.—E. C. S.

Magazine-Fed Press Tools. N. Bonamini. (*Machinery*, 1952, **81,** Aug. 7, 242–245). Where double-acting presses are not available, and it is not desirable to provide progressive tools for the production of parts involving several operations, press tools equipped with magazine feeding devices can often be used with advantage. This method of loading frequently results in an increased rate of output and greater safety for the operator, without being unduly expensive.—E. C. S.

Stacked Conveyors Boost Pressline Flexibility. G. Corsi. (*Machinery*, 1952, **96,** Aug. 16, 1270–1272). Belt conveyors stacked six high, plus special adjustable elevators, handle parts automatically with no loss of flexibility in the setup and operation of the presses.—E. C. S.

Sheet Metal Forming without Vertical Press Movements. (*Machinery*, 1952, **81,** Sept. 18, 631–633). Douglas Aircraft Co., Santa Monica, Calif., has developed a new rubber-pad process. The press required is a horizontal direct-acting, hydraulic one. It is only about one-tenth the size of a comparable press required for the Guérin process, but it is capable of delivering up to three times the pressures which are currently employed for this type of work. The hydraulic pressure in forming is confined entirely to the rubber bag. The higher pressures available make it possible to form the heavier gauge metals used in modern high-speed aircraft.—E. C. S.

Press Shop with Basement for Facilitating Installation and Re-Arrangement of Plant. (*Machinery*, 1952, **81,** Sept. 18, 634–635). The principal feature of the new press shop completed and put into operation by the Chrysler Corp., Detroit, is the ease with which presses can be installed and moved.

Plough Mould Boards Press-Formed to Shape. O. Nelson. (*Machinist*, 1952, **96,** Aug. 16, 1278–1279). The author describes how the International Harvester Co. produces a wide variety of plough shares and at the same time has kept down the tooling costs.—R. A. R.

Bending Tubes to Different Radii with a Triple Die. (*Machinery*, 1952, **81,** July 17, 121–122). Output of tubular frames for commercial vehicle seats has been substantially increased and handling costs reduced at the works of the Randall Co., Wilmington, U.S.A., by equipping a Pines automatic production bending machine with a triple radius die. This enables the workpieces to be completed on one machine with no tool changes.—E. C. S.

6-Stage Progressive Die Forms Heavy Stock. (*Machinist*, 1952, **96,** Oct. 4, 1620–1621). Progressive dies are not limited to small, thin-gauge articles. Details of a tool that is indicative of the trend toward making large, heavily formed parts from wide, thick strip in order to save press setups, labour, and inspections between operations, are given.—E. C. S.

Use of ' Draw Clips ' for Forming Sheet Metal Parts with Rubber Dies. J. A. Whittingham. (*Machinery*, 1952, **81,** July 17, 103–108). Recent developments by the aircraft

industry in methods of forming sheet-metal parts in hydraulic presses have resulted in increased efficiency and have extended the scope of the rubber-forming process utilizing inexpensive tools at the Columbus, Ohio, plant of North American Aviation, Inc.—E. C. S.

Machines for Cold Forming Strip. C. Hölzer. (*Machinery*, 1952, **81,** Sept., 428–434, 437). Sections may be produced from sheet or strip by bending performed by rollers, by drawing, or by pressing. For the pressing operation (press folding or bending) fixed tools are employed, whereas the rolling method is based on rotating tools. Intermediate between these two methods of production is the drawing process, working with drawplates and sometimes roller sets. The article deals with the manufacture of straight, open and closed sections ; universal section rolling machines ; section draw benches ; the production of formed rings and segments ; truing and stabilizing ; and the contracting and expanding process.—E. C. S.

Machine Tools for Shaping Sheet Metal. G. Oehler. (*Schweissen u. Schneiden*, 1952, **4,** Sept., 336–340). The construction, working, and application of machinery for pressing, bending, shearing, and drawing sheet metal are described.—R. A. R.

Electronic Guards from Drop Hammers and Press Brakes. (*Machinery*, 1952, **81,** July 10, 72–74).

How to Shear to Closer Limits. J. J. Murphy. (*Machinist*, 1952, **96,** Oct. 11, 1660–1663). Accurate shearing requires good gauging methods. The article describes how standard equipment can be applied to get better shearing at lower cost, both at the shears and on subsequent operations.—E. C. S.

Guards for Press Brakes and Presses. (*Machinery*, 1952, **80,** June 16, 1111–1114). Full technical details are given of a guard for press brakes and presses which has been developed by the A.P.V. Co., Ltd., London.—R. A. R.

Fencing of Presses. (*Metal Ind.*, 1952, **81,** Aug. 29, 170, 171). A brief description and illustration is given of a modern photoelectric guard system, designed by Radiovisor Parent Ltd., for use on press brakes and similar machinery.—P. M. C.

Drawing Metals into Wire. M. Bonzel. (*Métaux-Corrosion-Indust.*, 1952, **27,** Apr., 143–149). A short mathematical review of the mechanism of metal deformation is given. The effects of various die shapes and of temperature on wire drawing are discussed. Various methods of preparation of the metallic surface before drawing, lubrication during drawing, and thermal treatment of the wire after drawing, are described.—B. G. B.

Diamond Wire-Drawing Dies. R. E. Leeds. (*Metal Ind.*, 1952, **81,** Aug. 22, 147–148). Piercing diamond dies using steel needles and suspensions of diamond powder in oil, is a very long and tedious operation when bores of only a few thousands of an inch are required. An improved method of piercing with an electric spark, which enables times to be reduced by a factor of 50, is described. The method, developed by The General Electric Co., enables bores to be produced down to 0·0002 in.—P. M. C.

Some Friction Effects in Wire Drawing. G. D. S. MacLellan. (*J. Inst. Metals*, 1952, **81,** Sept., 1–13). A generalized version of Sachs's theory, to allow for the effect of a cylindrical extension to a conical die channel, is presented. Previously published results are reviewed and results from further experimental investigations are given. It is concluded that these extensions have an appreciable effect on the drawing force, and that allowance must be made for their effect in the derivation of coefficients of friction from back-pull experiments. Some experiments with ' split ' dies are also described, but the results were inconclusive.—B. G. B.

A New Coating Process for Mechanically Descaled Patented High Carbon Wire. Part I. H. Trembicki. (*Wire and Wire Products*, 1952, **27,** May, 473–475). Mechanical descaling has been introduced at the wire mill of the Trembicki Co., Chicago, where the scale is removed by passing the wire over three very small sheaves set at an angle of 120°. The wire is then coated with ' Tioxicoat ' and cold drawn without any acid pickling. This high-carbon steel was successfully cold drawn from 0·155 to 0·064 in five drafts and its properties were satisfactory.

The Perfect Profile—A Yardstick. F. Mortimer. (*Wire and Wire Products*, 1952, **27,** Aug., 783–784, 827). A description is given of the method of measuring wire-drawing die bores using the instrument developed by B.I.S.R.A. Some of the faults in die construction thereby disclosed are discussed. There still is much room for improvement to the design and manufacture of dies.—J. G. W.

Composite Drawing Blocks. J. Wohak. (*Draht : Wire Production*, 1952, **1,** Sept., 10–14). Composite steel dies for drawing wire into different sections are discussed. The composite die inserts, which are made of tool steel, are tapered, and are placed in a similarly tapered straight carbon steel frame. For highly complicated sections, the inserts are made of abrasion resistant steel and located in heat-treated steel frames by means of adjusting screws.—J. G. W.

ROLLING-MILL PRACTICE

Modern Rolling-mill Drive at Redbourn Works, Richard Thomas and Baldwins, Ltd.: Electrical Equipment for 42½-in. Cogging Mill. (*Iron Coal Trades Rev.*, 1952, **165,** Sept. 12, 577–579). A description is given of the electrical equipment for the main and auxiliary drives of the 42½ in. cogging mill at the Redbourn Works of Richard Thomas and Baldwins, Ltd. The mill incorporates the most modern electrical drives and controls, failure being announced audibly and followed by automatic shut-down after 3 min.—G. F.

Electrical Drive for a 42½ in. Cogging Mill. (*Engineer*, 1952, **194,** Aug. 29, 281–284). The rolling-mill plant at The Redbourn Works of Richard Thomas and Baldwins, Ltd., Scunthorpe, consists of a battery of gas-fired soaking pits, a 42½-in. cogging mill, a bloom shear, and a 36-in. stand finishing mill. An average weekly output of about 6000 to 6500 tons finished weight of billets and slabs is obtained. A description of the electrical drive of the cogging mill, with particular reference to the General Electric Co. cascade exciter control system is given.—M. D. J. B.

On the Mechanization of Heavy Work in Rolling Mills. B. Sládek and J. Rychtařík. (*Hutnické Listy*, 1952, **7,** 5, 246–247). [In Czech]. Recent developments leading to the lightening of heavy manual work in Czechoslovak rolling mills are surveyed.—P. F.

Apparatus for the Direct Measurement of Rolling Moment. V. V. Nosal' and A. E. Gurevich. (*Zavodskaya Laboratoriya*, 1950, No. 3, 348–351). [In Russian]. An apparatus for the direct measurement of rolling moments, in which the torsion of the shaft transmitting the moment causes the capacities of a number of condensers to change, is described. The condensers consist of a number of insulated stainless steel plates disposed along the shaft. The change in capacity unbalances a bridge, the effect being followed oscillographically. The apparatus has been used successfully on a 250-mm., two-high laboratory mill. Details are given of the calibration of the apparatus.—S. K.

Time Study in the Rolling Mill. E. Kráčmar. (*Hutnické Listy*, 1952, **7,** 4, 182–186). [In Czech]. A time study is made of rolling-mill operations, and the equipment and the methods of work required for the most rational procedure are derived. Examples are cited in which such an analysis prevented unnecessary capital expenditure.—P. F.

The Plastic Behaviour of Rotating Steel Rollers Having Point Contact. G. Niemann and K. W. Kraupner. (*VDI Forschungshaft* 434, 1952, 5–15). By running the edge of a test disc under load between two larger discs, all surfaces being ' barrelled ' to secure point contact, the conditions under which plastic deformation started, and its course under repeated rolling, were found. The effect of load, speed, hardness of roller, initial curvature, and lubrication were all examined. The favourable effect on subsequent behaviour of a short initial period under a heavy preload was demonstrated.

Wax Filamented Model Billets Aid Study of Material Flow. J. L. Holmquist. (*Product Eng.*, 1952, **23,** Apr., 158–163). Experiments have been conducted with a quarter-scale model piercing mill and wax billets containing coloured wax filaments; these have revealed much information concerning the flow and deformation occurring in the Mannesmann process. Deformation includes twist, and circumferential and longitudinal shear. The method for deducing the material flow from the final shape and position of the filaments is explained.—A. M. F.

Metal Flow During Rolling of Asymmetrical Sections. Z. Wusatowski and A. Wojtylak. (*Prace Instytutu Metalurgii*, 1952, **4,** 2, 99–109). [In Polish]. Using Lendl's formula for the coefficient of mean elongation for composite profiles, as well as Wusatowski's formula for the coefficient of free elongation and spread, the authors have worked out a method of controlling roll-pass design for irregular and asymmetric sections.

Mean Coefficient of Linear Elongation during Rolling. J. Gorecki. (*Hutnik* (Katowice), 1952, **19,** 6, 197–201). [In

Polish]. A comparison of the results of calculations of the mean coefficient of linear elongation, using formulae of Puppe, Tafel, Lendl, and of the author, is made.—V. G.

South Africa Now Has Modern Steel Plant. (*Blast Furn. Steel Plant*, 1952, **40**, Aug., 933–934). A brief description of the new plant at Vanderbijl Park is given. A slabbing-blooming mill, a continuous hot strip mill and cold reduction mill are in operation. A large quantity of galvanized sheets, produced by the Sendzimir process, is manufactured.—B. G. B.

Details of Modernization of Certain Rolling Mills in France and Belgium. A. McLeod. (*Sheet Metal Ind.*, 1952, **29**, Sept., 773–783). The author describes and illustrates some recently laid down rolling mills and ancillary plant at the following works : Forges de Leval-Aulnoye ; Phenix Works, Liége ; and Ferblatil (S.A. John Cockerill).—P. M. C.

Formula for Computing Length of Rod Mill Loop. A. B. Cox. (*United Effort*, 1952, Mar.–Apr., 11). The derivation of a simple formula is given. It is claimed that the method is direct and accurate, and that it can be reversed to find the permissible percentage reduction for a loop of a given length.

Farewell to Merchant Bar Mill. O. Luder. (*Roll'schen Eisenwerke Werkzeit*, 1952, **23**, Jan., 19–22). The history of two old rolling mills at von Roll works, Gerlafingen, Switzerland, is traced. The building to house the new mill is ready.

Foreign, in particular Swedish, Steel Bar and Wire Rod Rolling Mills. T. Dahl. (*Stahl u. Eisen*, 1952, **72**, May 22, 605–611). The modern Swedish bar mills all have precision couplings and flexible drives, roller bearings in every stand, thin short work rolls in the finishing trains, specially stiff housings, roller guides for every stand, high-pressure water for improving surface quality, and, finally, extensive mechanization. All sections under 50 mm. square as well as oval, diamond, flat, and hexagon intermediate sections are automatically repeated and fed. The installation of the roller bearings, the special housings, and the roller guides are described. The mechanization of American bar mills and the advantages of open finishing trains with single drive are discussed and the three latest mills at Hofors, Degerfors, and Fagersta are described.—J. P.

Deformation Ratios in the Thyssen Method of Rail Calibration. H. Vollmacher. (*Stahl. u. Eisen*, 1952, **72**, May 22, 611–616 ; *Iron Steel Inst.*, 1952, *Translation Series No.* 452). One of the most objectionable defects in railroad rails is cracking of the base. Although properly melted steel is a prerequisite for a reduced tendency to cracking, the actual rolling can compensate for metallurgical failures. The special design, developed by the August-Thyssen-Hütte and since adopted by many rail mills, is very suitable. Flow patterns on macro-etched specimens have indicated the advantages of this procedure and shown how a complete shifting of the crystallites and the displacement of a crack-free core to the outer surface of the rail base bring about a reduced tendency to cracking. Bend tests on rail bases have shown that the new procedure produces a marked improvement in mechanical strength.—J. P.

Developments in the Rolling of Broad Flange Beams at the Cargo Fleet Iron Company, Ltd. G. Barry Thomas. (*J. Iron Steel Inst.*, 1953, **173**, Feb., 113–118). [This issue].

The Measurement of Strip Tension in Tandem Mills. R. B. Sims. (*Engineering*, 1952, **174**, Aug. 22, 232–233 ; Aug. 29, 262–264). The author describes an instrument which will give a reliable indication of inter-stand tension. The equations for the deformations in the strip as it passes over the roller are established, and the experimental details and results are discussed. The development of the prototype tensiometer is described and details are given of an industrial interstand tensiometer installed in a 56-in. tandem mill rolling strip at 1700 ft./min.—M. D. J. B.

Details of a New High Precision Hot Rolling Line at Sandvikens Jernverks AB. (*Sheet Metal Ind.*, 1952, **29**, Aug., 717–722). This mill, designed and built by W. H. A. Robertson and Co. Ltd., is used for the production of high-grade steel, stainless steel, and razor blade strip. The complete line occupies a building over 700 ft. long and comprises : Scale breaker ; two 3-high roughing mills ; 3-high intermediate mill ; and 5-stand continuous finishing train. Details, layout, and illustrations of the plant are given.—P. M. C.

New Sendzimir Mill for Ultra-Thin Strip. (*Sheet Metal Ind.*, 1952, **29**, May, 398, 399). Details and illustrations are given of a new 4-in. wide mill designed for the production of strip down to 0·0002 in. thick. The maximum entry gauge is 0·010 in. and strip tension can be controlled within the range of 10 to 400 lb. The mill is of 1–2–3–4 construction ; the nominal work roll diameter is 0·25 in.; the first intermediate roll diameter is 0·5 in.; the second intermediate rolls are 1-in. (centre idler) and 1·094-in. (outer driven). Maximum speed is 300 r.p.m., the main motor being 7½ h.p. and the winder motors 3 h.p. each.—P. M. C.

Continuous Gauging of Strip Thickness. H. Manley. (*Sheet Metal Ind.*, 1952, **29**, May, 389–394). The author gives details and illustrations of a wide range of British and American gauges, including both mechanical and ray-type equipment. Working ranges and circuit details are given for several X-ray and Beta-ray gauges.—P. M. C.

The "Ferblatil" Company, Makers of Tinplate and Cold-Rolled Sheet. R. A. Lamalle and E. Wilmet. (*Ossature Métallique*, 1952, **17**, June, 297–307). The construction and the equipment of the continuous strip mill at Tilleur of the Ferblatil Co. Ltd., a subsidiary of the S.A. John Cockerill, is described.—P. F.

Review of Modern Methods of Producing Hot Rolled Strip in Continuous Mills. M. Gatti. (*Met. Ital.*, 1952, **44**, July, 250–258). [In Italian]. Developments since 1924 in the production of sheet and plates in continuous mills are reviewed. The plants now being installed comprise : Continuous mills with four blooming stands and six finishing stands, with capacities exceeding 600,000 tons/year ; semi-continuous mills comprising one reversing blooming stand and five or six continuous finishing stands with capacities ranging between 250,000 and 600,000 tons ; and lastly, Steckel four-high reversing mills with reeler and soaking furnaces installed at both ends and with capacities ranging from 125,000 to 250,000 tons/year.—M. D. J. B.

Steel for the Pipes of Plenty. A. G. Roach and R. W. Seely. (*Amer. Gas. Assoc. Monthly*, 1952, **34**, June, 9–11). The manufacture of steel pipes for the transportation and distribution of natural gas in America is discussed.—B. G. B.

Hydro-Electric Controls for Three-High Mills and Tables. R. J. Simes. (*Iron Steel Eng.*, 1952, **29**, July, 106–109). This article describes the controls of the Lukens 140-in. hot-plate mill. The unit consists of an electrically controlled, solenoid-operated, air-actuated hydraulic control valve. The system is in use on shears, flattening punching and forming presses, furnace doors, and mill table pushers.—M. D. J. B.

Developments in D.C. Drives for Hot Strip Mill Runout Tables and Coilers. H. E. Larson. (*Iron Steel Eng.*, 1952, **29**, July, 55–76). This paper summarizes experience and developments contributing to the improvement and reliability of runout tables and coiler performances. The author considers methods of driving table rolls and mounting table-roll motors, the effects of table-roll spacing, table performance, and drive cost, runout table speeds for various operating conditions, and speed synchronization with the mill. Test data are given, together with examples illustrating recommended methods for determining roll-motor rating and the number of table sections desirable.—M. D. J. B.

MACHINERY FOR IRON AND STEEL PLANT

Applying Research to Steel Works Plant and Operation. R. F. Jennings. (*Engineer*, 1952, **194**, July 18, 83–84). Very large sums of money are spent on large-scale research for the development of industrial processes, but it is suggested that this money is not used in the most effective way. The author claims that not enough research effort is devoted to the design of steelworks plant as compared with that expended upon the development of processes, and he gives examples of items of plant, the design of which might be improved through the application of operational research.—M. D. J. B.

Electric Distribution in Iron and Steel Works: Planning and Operation of the Installations at the Margam and Abbey Works. T. B. Rolls and E. C. Slater. (*J. Iron Steel Inst.*, 1953, **173**, Feb., 163–176). [This issue].

New Fault Detector for Electrical Systems. W. L. O. Graves and L. R. Foote. (*Blast Furn. Steel Plant*, 1952, **40**, Sept., 1064–1065). The fault detector, which is described, consists of a row of glow lamps. When a fault occurs, the location of the fault is indicated by these lamps.—B. G. B.

Speed Regulation of Slip-ring Induction Motors for Special Purposes. F. Dahlgren and P. Biringer. (*Acta Polytechn.*, 1951, No. 99, Elect. Eng. Series **4**, No. 4). A theoretical and experimental investigation has been carried out relating to a particular arrangement for speed regulation of a slip-ring

induction motor within certain regions of operation. These regions of operation are high-speed service at low torque, where the arrangement renders over-synchronous motor service, at full torque, and low-speed reverse-field braking at full torque.—J. C. B.

Oil Injection Shrink Fitting. J. A. Abrahams. (*J. Iron Steel Inst.*, 1953, **173**, Feb., 118). (This issue).

Golden Jubilee of Heenan & Froude, Ltd. (*Mech. Handling*, 1952, **39,** Oct., 496–499). Details are given of a visit by the technical press to Heenan & Froude, Ltd., and Fielding and Platt, Ltd., on the occasion of the golden jubilee of their incorporation. The latter company manufacture hydraulic riveters, presses, pumps, accumulators and heavy forging presses, and the former company make baling presses, engine testing equipment, and automatic machinery for the wire, strip and chain industries.—R. A. R.

Care and Maintenance of Electric Overhead Travelling Cranes. (*Mech. Handling*, 1952, **39,** Aug., 383–385). A brief description is given of a guide to the maintenance of overhead cranes issued by the Wharton Crane and Hoist Co., Ltd. Complete details are given for plant lubrication.—D. H.

Noble and Lund Double-Ended Ingot Parting Machine. (*Machinery*, 1952, **81,** Aug. 7, 252–253). This machine which was constructed for English Steel Corp., Ltd., Sheffield, can also be employed for turning ingot moulds. It accommodates ingots from 4 ft. to 10 ft. 3 in. in dia., and up to 30 ft. long, with maximum weights up to 300 tons.—E. C. S.

Try this Plan for Industrial Truck Maintenance. M. A. Lyons. (*Machinist*, 1952, **96,** Oct. 4, 1624–1626). Details of a plan to cut repetitive repairs, to eliminate unexpected breakdown, and to guide equipment purchasing and replacement, are given by the Supervisor of Transportation and Service Division, Westinghouse Electric Corp.—E. C. S.

Four-Roll Plate-Bending Machine. (*Engineering*, 1952, **174,** Aug. 1, 140–141). A description is given of a plate bending machine made by the Bronx Engineering Co., Ltd., Lye. The machine is capable of dealing with mild-steel plate up to 8 ft. by $\frac{3}{8}$ in. or 5 ft. by $\frac{1}{2}$ in. and can carry out all normal bending operations.—M. D. J. B.

Oscillations in Statically Supported Rolling Bearings—A Contribution to the Analysis of Noise from Lightly Loaded Rolling Bearings. H. Perret. (*VDI Forschungsheft* 434, 1952, 17–28).

LUBRICANTS AND LUBRICATION

The Lubrication of Ball and Roller Bearings. (*Scientific Lubrication*, 1952, **4,** Sept., 12–15). After an account of the history and general types of anti-friction bearings, and the factors which produce frictional effects, the duties of lubricants are considered. These are : To prevent bearing contamination, to prevent corrosion or erosion, to reduce sliding friction and wear, and to dissipate heat generated in the bearing.

Grease Lubricator for Heavy Plant. (*Engineering*, 1952, **174,** July 25, 126–127). **Lubrication of Large Rolling Mills.** (*Sheet Metal Ind.*, 1952, **29,** June, 498, 499). **A New Roll Mill Lubricator.** (*Scientific Lubrication*, 1952, **4,** May, 26–29). Details are given of a new centralized lubrication system installed on a 42-in. Davy slabbing mill at the Appleby-Frodingham Steel Co. The system is automatic, giving an accurately regulated forced feed to every lubricating point through individual pumping units, and giving warning if any bearing is not receiving its lubricant supply.—K. E. J.

Automatic Lubricator for Rolling Mills. (*Metallurgia*, 1952, **45,** June, 301–302). The lubricator is of new design and unusually compact, but operates by the old method of every bearing being fed with grease by a piston which is actuated by oil under pressure. The design and operation of the lubricator are described.—B. G. B.

Phosphate Coatings in Cold Forming. R. H. Warring. (*Mech. World*, 1952, **131,** May, 202–204). The use of phosphate coating to produce a non-metallic, strongly adhering skin of the proper texture to retain lubricant and so aid the forming of stainless and other steels, aluminium, brass, and bronze is discussed.—D. H.

Measurement of Extreme Pressure Properties of Lubricants. L. Levin, H. G. Sprague, and others. (*A.S.T.M. Bulletin*, 1952, Apr., 43–46). The results of tests on the Timken test machine, which have been quoted and used in oil specifications, are given. Rather poor precision was obtained, and the investigation shows that a lubricant may be classified into one of three extreme pressure levels: Low, medium, or high. To discriminate between oils on the basis of small differences in Timken results is not warranted. An outline of the test procedure is given.—B. G. B.

WELDING AND FLAME-CUTTING

Welding Characteristics of Materials for Aircraft Gas Turbines. A. J. Rosenberg. (*Welding J.*, 1952, **31,** May, 407–412). Welding characteristics and metallurgical properties of high-strength sheet metal used for gas turbines are studied.

Metal Transfer in Sigma Welding. R. T. Breymeier. (*Welding J.*, 1952, **31,** May, 393–399). Metal transfer in the arc is studied by ultra slow-motion photography. The effects of different welding conditions, current, gas mixtures, and rod material are discussed.—U. E.

Welding Heat Exchangers for the Chemical Industry. J. W. Mortimer. (*Welding J.*, 1952, **31,** May, 387–392). Different types of heat exchanger and their fabrication by welding are described and illustrated.—U. E.

Study of the Behaviour of Steels During Welding by the Method of Crossing Gradients. H. Granjon. (*Compt. Rend.*, 1952, **235,** July 16, 173–175). A vertical cylindrical bar is heated by an oxy-acetylene burner and then cooled by water forced through an axial hole. Two superimposed gradients of maximum temperature and of speed of cooling are thus established, and, from a single test, a correlation fixing the co-ordinates of representative points in the transformation zone of welds can be established.—A. G.

Transmission Assemblies Arc-Welded Automatically. H. Chase. (*Steel*, 1952, **130,** Apr. 28, 74–75). Automatic operation of special arc-welding machines is facilitating the joining of parts for transmission assemblies. A complete cycle on one part has been reduced to 15 sec. by speeding up the loading and unloading. Indexing is done by air, and motions are cushioned by dashpots.—A. M. F.

Shielded, Submerged Arc Welds Withstand Rugged Service. F. R. Drahos. (*Steel*, 1952, **130,** Apr. 14, 94–96). The use of the submerged-arc method for welding large components for heavy-duty assemblies is discussed. The electrodes must be correctly chosen to duplicate the physical or chemical properties of the material to be fusion welded, and correct heat-treating and welding techniques must be employed.—A. M. F.

Stud Welding Cuts Fabrication Time. (*Iron Age*, 1952, **169,** Apr. 24, 146–147). The use of end-welded studs in the manufacture of railway wagons and carriages is described.—A. M. F.

Welded Construction at the Abbey Works. A. V. Hooker. (*Rev. Soudure*, 1952, **8,** 3, 118–127). Details are given of some of the welding work at the Abbey Works of the Steel Company of Wales, Ltd.—R. A. R.

The Effects on the Human Eye of the Radiant Energy Given off by Various Welding Processes. C. C. Bates. (*Sheet Metal Ind.*, 1952, **29,** Apr., 349–352, 357 ; May, 435–440, 447). The first instalment describes the human eye and also deals with the measurement of radiations, the range of radiation given off by the electric arc, and the effects of the infra-red and visible radiations on the eyesight. The second part considers ultra-violet radiations, 'arc-eye' and its treatment, filters, and goggles.—P. M. C.

Unusual Soldering and Brazing Operations Performed in Heat-Treating Furnaces. (*Indust. Heating*, 1952, **19,** Apr., 624–628). Soldering instruments to metal backs, brazing glass and ceramics, and soldering aluminium with pure tin are among the operations mentioned.—B. G. B.

Production Brazing and Soldering by High Frequency Methods. F. Spicer. (*Mech. World*, 1952, **132,** July, 16–18). The author explains briefly the theory of high-frequency heating and the types of generator and coils used. Brief mention is made of brazing materials and fluxes.—D. H.

Furnace Brazing : Atmospheres Set the Pace. S. Damon. (*Steel*, 1952, **130,** May 5, 102–104, 127–128). The developments in protective atmosphere furnaces have widened the application of brazing techniques to practically all metals. The requirements for brazing nickel, molybdenum, plain and stainless steels, and cast iron are described. Atmospheres to be used where decarburization must be prevented call for very low dewpoints, and, in these cases, a metallic-muffle furnace must be employed.—A. M. F.

Brazing Hydromechanics. E. R. Funk and H. Udin. (*Welding J.*, 1952, **31,** June, 310s–316s). Factors affecting the rate of completion of a brazed joint are studied by the

application of the elementary laws of hydromechanics. Equations are derived which relate the physical constants of the brazed metal, its surface tension, and joint dimensions to the interface velocity of both vertical and horizontal joints.

MACHINING AND MACHINABILITY

A Successful Experiment with Broaches. W. Jubb. (*Metallurgia*, 1952, **45**, Jan., 11). An account is given of the manufacture of a set of broaches from a 3% nickel–chromium case-hardening steel (En 36) which gave an output of over 10,000 components without a regrind. Standard carbon case-hardening steel (En 32A) was also used for broaches but possessed too low a core strength, causing collapse of the case among other defects.—B. G. B.

Jet Alloys Toss Challenge to Machine Tools. P. G. DeHuff and D. C. Goldberg. (*Steel*, 1952, **130**, Apr. 28, 76–78). The problems involved in the machining of high-temperature alloys for jet engines are discussed. More rigid machines with higher horsepower motors are called for.—A. M. F.

Shaping, Finishing Horizons Widen. (*Steel*, 1952, **130**, Apr. 7, 120, 140–144). Machining methods for carbides, which may replace diamond wheel grinding, include electrolytic, electrosparking, electroarcing, and ultrasonic processes. Electrosparking and ultrasonics are in use on a production scale for the shaping and finishing of dies. Research and development on all these processes are necessary for further applications, but the methods appear promising.—A. M. F.

Hi-Jet System for Increasing Tool Life. R. J. S. Pigott and A. T. Colwell. (*S.A.E. Quarterly Trans.*, 1952, **6**, July, 547–566). *See* " Squirt Outdoes Flood in Cooling Cutting Tools " (*J. Iron Steel Inst.*, 1952, **172**, July, 239).

Shaping Sheet Metal by Means of the Band Saw. H. J. Chamberland. (*Sheet Metal Ind.*, 1952, **29**, May, 412–414). The author describes modern methods and achievements in both friction and high-speed cutting. Material thicknesses, cutting rates, and saw-blade design are dealt with.—P. M. C.

Fast Cutting of Metal by Better Mechanical and Metallurgical Engineering. (*Metal Progress*, 1952, **61**, June, 94–96, 120–122). The question of temperature in relation to machinability, especially as it affects tool life, is discussed. Six causes of carbide tool failure are outlined and probable remedies are suggested. Microstructural correlations pertaining to machinability have been shown in grey cast irons, ductile irons with spheroidized graphite, and a few high-temperature alloys. Improvement in tool life is achieved by decreasing the combined carbon in the grey and ductile irons.

How Ford Plans for Low-Cost Chip Handling. M. J. Rowan. (*Machinist*, 1952, **96**, May 31, 830–834). Latest cost-cutting ideas developed by Ford engineers for chip handling and coolant purification in the new Cleveland engine plant are described. Cast-iron chips, wet steel chips, and grinding sludge are handled in systems which often depart from conventional practice to obtain greater efficiency.—E. C. S.

Lagooning Purifies Metalworking Wastes. (*Steel*, 1952, **130**, Apr. 14, 98–100). Non-toxic metalworking wastes consisting mainly of soluble oil emulsions are treated successfully and economically by a lagooning system at the Salisbury Axle Works, Fort Wayne, Ind. The system consists of a settling pit and two detention basins which handle 200,000 gal./day.

CLEANING AND PICKLING

Note on the True Efficiency of Inhibitors in Pickling. L. Cavallaro and L. Felloni. (*Met. Ital.*, 1952, **44**, Aug.–Sept., 366–370]. The authors advocate the use of inhibitors in pickling liquors because these slow down the attack on the metal and accelerate the solution of the oxygen. These effects are examined in detail as well as the behaviour of the three systems metal–acid, oxide–acid, and metal–oxide–acid. The effects of the presence of oxide on the speed of attack on metal, and of the presence of metal on the speed of solution of the oxide were also studied, together with the ' real ' efficiency of certain groups of organic substances used as moderators. (10 references).—M. D. J. B.

Conservation of Sulphuric Acid and Nickel Sulphate in the Pickling Department. M. H. Whitehead. (*Products Finishing*, 1952, **16**, Aug., 36–42). Some hints are given to avoid wastage of sulphuric acid and nickel sulphate in the pickling department of a vitreous enamelling shop.—J. P.

Cleaning Metals. F. Spicer. (*Machinery*, 1952, **81**, Aug. 21, 328–331). Chemical, physical, and mechanical cleaning methods are briefly considered.—E. C. S.

A Metal Cleaning Test Using Radioactive Stearic Acid as Soil. J. W. Hensley, H. A. Skinner, and H. R. Suter. (*Metal Finishing*, 1952, **50**, July, 49–52 ; Aug., 77–80, 83). Reproducible and relatively simple procedures have been developed to test metal cleaners, using labelled stearic acid as soil. The ease of removal of films of stearic acid depends on surface finish of the steel to which they are applied, and a standard mechanical abrading process has been devised. The differences in soil-removal powers of five common alkali detergents and an alkyl-aryl sulphonate are clearly demonstrated.—J. P.

Felt for Metal Finishing and Polishing. L. D. Gruberg. (*Metal Finishing*, 1952, **50**, Sept., 58–63).

PROTECTIVE COATINGS

Saturation of a Steel Surface with Vanadium from a Gaseous Medium. G. N. Dubinin. (*Doklady Akademii Nauk S.S.S.R.*, 1952, **84**, 2, 269–272). [In Russian]. Saturation of steel surface with vanadium, using ferrovanadium and mixtures of hydrogen and hydrogen chloride in accordance with the reaction $VCl_2 + Fe \rightleftharpoons FeCl_2 + V$, was investigated. Experiments were made using iron and steels with the carbon rising in 0·2% stages from 0·1 to 1·2%. The temperature of the process was varied from 800° to 1300° C. Micrographs of vanadium-impregnated steel surfaces are shown. Spectroscopic analysis indicated that the concentration of vanadium at the surface varies, depending on the experimental conditions, for iron from 9 to 50%, and for steel, up to 70%. The results of the spectrum analysis showing changes in concentration with depth are given. X-ray analysis showed that, in the case of iron, the surface layer consisted of a solid solution of vanadium in iron, and in the case of steel, vanadium carbide (VC) was formed. The results of electron defraction studies and measurements of microhardness of the cooled surfaces are given.—V. G.

Saturation of Steel Surface with Molybdenum from a Gaseous Medium. G. N. Dubinin. (*Doklady Akademii Nauk S.S.S.R.*, 1952, **84**, 5, 935–938). [In Russian]. Coating of iron (0·03% C) and steel (0·1 to 1·2% C) surface with molybdenum by diffusion from a gaseous medium in accordance with the reaction $mMOCl_n + nFe \rightleftharpoons nFeCl_m + mMo$ was investigated. The temperature of the process was 900–1300° C. It was found that the velocity of the diffusion of molybdenum in the α-phase is considerably higher than that of tungsten. The structure of the treated surfaces is described, and the improvement in resistance to corrosion is outlined.

Saturation of Steel Surface with Tungsten from a Gaseous Medium. G. N. Dubinin. (*Doklady Akademii Nauk S.S.S.R.*, 1952, **84**, 4, 693–696). [In Russian]. The method of coating iron (0·03% C) and steel (0·1 to 1·2% C) with tungsten by diffusion from a gaseous medium in accordance with the reaction $mWCl_n + nFe \rightleftharpoons nFeCl_m + mW$ was investigated. The process was conducted at 900–1300° C. The structure of treated surfaces is described and the improvement in resistance to corrosion is outlined.—V. G.

Saturation of Steel Surface with Manganese from a Gaseous Medium. G. N. Dubinin. (*Doklady Akademii Nauk S.S.S.R.*, 1952, **84**, 6, 1155–1158). [In Russian]. Coating of iron (0·03% C) and steel (0·1 to 1·2% C) with manganese by diffusion from a gaseous medium in accordance with the reaction $mMnCl_n + nFe \rightleftharpoons nFeCl_m + mMn$ was investigated. The process was conducted at 800–1200° C. The structure of treated surfaces is described. The resistance to corrosion in water was improved, but the resistance to acids was diminished.—V. G.

Surface Protection of Steels by Aluminium Coatings. J. Chvojka. (*Hutnické Listy*, 1952, **7**, 5, 227–231). [In Czech]. The technical and economic aspects of methods suitable for coating steel with aluminium are discussed.—P. F.

Complex Parts Easily Coated with Aluminium. W. G. Patton. (*Iron Age*, 1952, **169**, June 12, 115–118). General Motors has developed a dipping process which puts a sound aluminium coating on fabricated steel parts of complex shape. The purpose is to give heat and corrosion resistance to the parts. An essential part of the process is a preheat and flux bath before the aluminium dip bath, which is induction heated. The resulting microstructure is in two layers, iron-bearing aluminium over a layer of iron–aluminium alloys.—A. M. F.

Physical Basis of the Formation of Metallic Coatings Sprayed on with the Gas-Heated Wire Gun. K. Krekeler and H. Rabenschlag. (*Metalloberfläche*, 1951, **5**, May, A71–A74). The theories of metallizing advanced by Schoop, Schenk, Karg, and others are reviewed, and experiments testing the hypotheses involved in these theories are described. It is concluded that after having been melted and atomized in the spray gun, the metal travels in a soft state towards the surface to be coated, and is flattened by plastic deformation upon impact. This plasticity facilitates close adherence of the particles which, immediately after impact, are chilled by the cool gas or air stream from the gun. No welding of particles takes place as they are generally separated from one another by grain-boundary oxides. The metal deposits form layers. This was confirmed by the microscope.—P. F.

Experience with Paint Coatings on Iron, Zinc, and Light Alloys. G. Hoffmann. (*Metalloberfläche*, 1951, **5**, May, B69–B71). The physical and chemical functions, and methods of applying corrosion-resistant paints are discussed.—P. F.

POWDER METALLURGY

Technology of Pre-Alloyed Stainless Steel Powders—Properties, Production, Uses. A. H. Grobe and G. A. Roberts. (*Precision Met. Mold.*, 1952, **10**, July, 23–26; Aug., 36–38). Details are given of the main uses, properties and methods of production of five qualities of stainless steel powder made by the Vanadium-Alloys Steel Company, U.S.A., with data on the effects of sintering time and temperature on their mechanical properties and shrinkage.—D. H.

Practical Applications of Hot Pressing. J. F. Kuzmick. (*Mat. Methods*, 1952, **36**, July, 84–87). The author deals with the hot moulding process, in which pressing and sintering of a powder metal charge are performed simultaneously in one operation. The application to the manufacture of tungsten carbide dies, heavy metal components, and diamond-faced mining bits is briefly described.—P. M. C.

Carbide Dies Effectively Used in Powder Metallurgy. K. M. Gleszer. (*Precision Met. Mold.*, 1952, **10**, July, 31, 74–77). The author suggests the true causes and possible cures for most of the troubles encountered by the manufacturer when using cemented tungsten carbide dies, punches, and core rods.—D. H.

PROPERTIES AND TESTS

What Can Be Learned From the Hardness Test? H. E. Boyer. (*Steel Processing*, 1952, **38**, May, 223–227; June, 280–285, 298). The Brinell and Rockwell hardness tests are discussed, the latter being named as the more versatile. Some comments on the meaning of hardness, and on the care which must be exercised in the interpretation of results in the factory, are given. Errors introduced by too thin material, lack of flatness, and heterogeneous materials are dealt with. Other tests, notably the Knoop diamond and Vickers diamond methods, are discussed, and the use of such indenters for obtaining microhardness values on different phases of heterogeneous samples are described.—P. M. C.

Hardness, Elastic Modulus, Wear of Metals. T. L. Oberle. (*S.A.E. Quarterly Trans.*, 1952, **6**, July, 511–517). Since evidence shows that the wear of materials is closely related to the elastic limit of strain, the author proposes a new concept as a practical measure of this property. He introduces the term 'modell,' which he defines as the Brinell hardness multiplied by 10^6 and divided by the elastic modulus. As materials with high modell values have in general good wearing properties, the author discusses the possibilities of increasing the modell values for engineering materials.—P. M. C.

The Method of Determining Changes in Hardness of α and γ Phases in Steel during Heating to 1100° C. in a Vacuum. M. G. Lazinskii. (*Doklady Akademii Nauk S.S.S.R.*, 1952, **84**, 1, 63–66). [In Russian]. A description of the apparatus used for determining the hardness of steel at high temperatures *in vacuo* is given. The apparatus can also be used for the determination of the critical points.—V. G.

The Theory of Precipitation Hardening. R. L. Apps. (*J. B'ham. Met. Soc.*, 1952, **32**, June, 60–72). A qualitative review is given of the mechanisms of precipitation and the hardening arising from it, in the light of present-day dislocation theory. The effects of time and temperature are considered. (18 references).—P. M. C.

Conversions between Hardness and Tensile Strength of Steels. (*Nickel Bull.*, 1952, **25**, June, 142–145). A table is given which compares tensile strength with the diamond pyramid, Rockwell C and D, Brinell, and Scleroscope hardness scales. The data were prepared jointly by the A.S.T.M., the American Society for Metals, and the S.A.E.—P. M. C.

Hardness Measurements for Determination of Residual Stresses. G. Sines and R. Carlson. (*A.S.T.M. Bulletin*, 1952, Feb., 35–37). Experimental evidence of the effect of stress on the measurement of penetration hardness is presented. A method is suggested for measuring residual stresses by hardness measurements. This method and X-ray diffraction, which is limited in application, are the only non-destructive procedures for measuring residual stresses.—B. G. B.

Dynamometer for Checking the Loading Mechanism of Mircohardness Testing Machines. E. S. Berkovich. (*Zavodskaya Laboratoriya*, 1950, No. 3, 381–382). [In Russian]. A direct method of checking loading mechanisms with the aid of a simple dynamometer covering a range of 1 to 5 g. is described. The sensitivity of the dynamometer is $\pm$ 10 mg.

Three-Faced Diamond Pyramid for Micro-Hardness Testing by Indenting. E. S. Berkovich. (*Zavodskaya Laboratoriya*, 1950, No. 3, 345–347). [In Russian]. The advantages of three-sided as against four-sided pyramids for microhardness testing are pointed out, and results obtained by the two types for steel, Cr-plated steel, and some non-ferrous metals and alloys are compared.—S. K.

Closer Hardenability Control for Silicon–Chromium Steel. B. C. Schott and S. Isenberg. (*Steel*, 1952, **130**, Apr. 7, 114–115). During investigations of several heats of a silicon–chromium valve steel it has been observed that higher silicon tended to decrease the steel's hardenability. This anomalous behaviour is due to a faster critical reaction rate rather than to graphitization. These studies should result in a closer control of hardenability and a better understanding of quenching reactions.—A. M. F.

Strain Hardening and Aging: Behaviour of Some Commercial Low-Carbon Steels. H. A. Unckel. (*Iron Steel*, 1952, **25**, June, 273–278). Results are given of a study of the quench-ageing and strain-ageing behaviour of commercial low-carbon steels, and of the effects on these phenomena of cold-working, annealing after cold work, and normalizing. The investigation appears to confirm that quench-ageing is due to carbon and strain-ageing to nitrogen, and indicates that the decrease of quench-ageing with increase in carbon above the solid solubility limit is possibly due to precipitation on already existing carbides.—G. F.

The Effect of Quench-Aging on the Notch Sensitivity of Steel. J. R. Low, jun. (*Welding J.*, 1952, **31**, May, 253s–256s). Charpy impact test specimens of a semi-killed 0·20% carbon steel were quenched from 690° C. and aged at room temperature for periods up to three years. During this period the transition temperature increased from −40° to 0° C. Over-ageing at 350° C., either immediately following quenching or after three years' ageing, lowers the transition temperature to −15° C. It is suggested that quench-ageing is responsible for the commonly observed brittle zone adjacent to welds in this grade of steel and that a low-temperature post-heat-treatment should improve the low-temperature ductility of welded structures made of this and similar grades of steel. A decrease in the cooling rate from 690° C. raises the transition temperature. This is believed to account for the fact that as-rolled plates show an increase in transition temperature as the thickness increases.—U. E.

Hot Embrittlement of Austenitic Chromium–Nickel Steels. G. Hoch. (*Arch. Eisenhüttenwesen*, 1952, **23**, July–Aug., 257–275). The embrittlement of chromium–nickel steels in the temperature range 300–1000° C. has been investigated on 93 laboratory-prepared steels containing 12–27% Cr, 8–20% Ni, and 0·10%, 0·04%, 0·02%, and 0·35% C. Some of the steels contained additions of silicon, titanium, and niobium. The cause of the embrittlement, observed on impact or bend testing after heating for up to 1000 hr. at 600–900° C., was undoubtedly the precipitation of carbide, martensite, or the intermetallic compound FeCr. Impact tests carried out at the temperature of the annealing and at room temperature showed that the embrittlement by carbide and FeCr was practically as great at elevated as at room temperature. On the contrary, embrittlement by martensite, produced by holding at temperatures above the transformation point with subsequent cooling, appeared only on testing at room temperature. The impact tests were supplemented by thermomagnetic, saturation and hardness measurements, and metal-

lographic examination. A diagram has been constructed to indicate the extent of embrittlement and the structure after annealing at 700° and 800° C. as a function of the chromium and nickel contents. No explanation can be given for the embrittlement in tensile tests at 600–900° C. It was, however, determined that the causes were different from those responsible for the embrittlement on impact testing. Additions of the carbide-former titanium counteracted the reduction of deformation in tensile testing, but niobium did not.—J. P.

Method of Obtaining a Sharp and Constant Focus in Ionic X-Ray Tubes. V. P. Tekht. (*Zavodskaya Laboratoriya*, 1950, No. 3, 328–330). [In Russian]. Experiments are described which showed that, using a cathode in the centre of whose surface a hole has been drilled, gives an improved and more constant focus in ionic X-ray tubes and increases the cathode life.—S. K.

Semi-Automatic X-Ray Equipment for Faster Non-Destructive Testing. D. Goodman. (*Amer. Foundryman*, 1952, **22**, Aug., 6–63). This illustrated article describes the functioning of an apparatus that automatically irradiates parts to be tested, and develops the film behind the parts, so allowing rapid inspection.—E. T. L.

Gamma Radiography in the Foundry.—R. J. Hart. (*Inst. British Foundrymen Preprint*, 1040, June, 1952). The author describes the use of the three isotopes cobalt^{60}, tantalum^{182}, and iridium^{192}, for foundry radiography. The advantages of this non-destructive testing for defects include the fact that time is not spent on machining metal with concealed faults.

Measurement of Thickness by Radiation Methods. I—Measuring Thicknesss Less than 1 mm. with Beta-Rays. A. Trost ; **II—Measuring Thicknesses up to approximately 10 mm. with X-Rays and Counting Tubes.** H. W. Fritze ; **III—Measuring Thicknesses from 10 mm. to 100 mm. with Gamma-Rays and Counting Tubes.** W. Kolb ; **IV—Measuring the Thickness of Non-Magnetic Layers on Non-Magnetic Substrates with Beta-Rays and Counting Tubes.** R. Berthold. (*Stahl u. Eisen*, 1952, **72**, July 31, 941–947). I—The suitability of various types of radiation is discussed. Beta-rays can be used with an accuracy of about ± 1% on steel up to 1 mm. in thickness, X-rays with a similar accuracy up to 100 mm. thickness, and gamma-rays, because of their greater penetrating power, only on steel thicker than 10 mm. The most convenient sources of beta- and gamma-rays are Tl^{204} Sr,^{90} radium, and Ru^{106}. The relative advantages of the natural and artificial radioactive emitters are discussed. Tl^{204} principles and construction of equipment for continous measurement of foils are described. II—The employment of X-rays for continuous measurement of hot-rolled strip is described. The X-ray tube used is of the hollow anode type, and two beams, approximately at right-angles are selected by lead diaphragms. One beam passes through the strip to be measured and the other through a reference sheet of steel. The beams then fall on two proportional counters, the outputs of which are opposed, amplified, and applied to a meter. When the strip is off gauge the counting tube outputs are out of balance, and the meter indicates the degree of variation. III—The use of a radium gamma source and a proportional counter for measuring thicknesses of steel sheets, boiler drums, and tubes, is briefly described. Using a counter in the Geiger-Müller region, the optimum measuring range for Ir^{192} has been found to be 10–30 mm. thickness with an accuracy of ±2·5% to ±1·5%, and for Co^{60} the optimum range is 30–100 mm. with similar accuracy. IV—The intensity of X-rays emitted from a thin layer of a metal on a metallic or non-metallic support on excitation by a Tl^{204} beta-ray source is a function of the atomic number of the coating metal and the substrate, and of the thickness of the coating. This furnishes a method for determining coating thickness. Between a count tube and the surface to be examined is placed a Tl^{204} source. This is shielded so that it does not directly affect the counter. The electrons impinge on the surface and excite X-rays, the intensity of which are measured by the counter. A calibration graph is drawn from results on samples carrying coatings of known thickness. The accuracy of the method depends on the difference in the atomic numbers of the coating and substrate material, but even a difference of one in atomic number gives a measurable indication.—J. P.

A Study of Gases in Metals. W. Baukloh. (*Trans. Indian Inst. Met.*, 1950, **4**, 231–238). The author reviwes the problems of gases in metals and discusses the basic principles of solubilities. He presents formulæ for the solubilities of hydrogen and nitrogen in iron.—D. H.

The Solubility of Nitrogen in Iron Chromium Alloys. K. T. Kuroczkin, P. V. Geld, and V. I. Yavoiskii. (*Doklady Akademii Nauk S.S.S.R.*, 1952, **84**, 2, 329–332). [In Russian]. The solubility of nitrogen in iron–chromium alloys (3·56–60% Cr) was investigated at temperatures of 1500° and 1670° C. and at nitrogen pressures of 735 and 512 mm. Hg. The results of metallographic investigations of cooled samples and measurements of microhardness are briefly outlined.

Solubility of Oxygen—Activity in Iron–Vanadium Alloys. R. A. Karasev, A. Yu. Polyakov, and A. M. Samarin. (*Doklady Akademii Nauk S.S.S.R.*, 1952, **85**, 6, 1313–1316). [In Russian]. Equilibrium was obtained between liquid iron containing vanadium and a gas phase containing controlled proportions of hydrogen and steam. The initial materials were electrolytic iron (C 0·005, P 0·0012, S 0·01–0·02%, and traces of silicon) and chemically pure vanadium trioxide. The reaction took place in corundum crucibles. The oxygen in the solidified metal was determined by vacuum fusion. Equations are derived from the data obtained for the reactions between vanadium dissolved in molten iron and oxygen for different vanadium concentrations.—V. G.

Further Investigations into the Effect of Hydrogen on the Tensile Properties of Steel. J. D. Hobson and J. Hewitt. (*J. Iron Steel Inst.*, 1953, **173**, Feb., 131–140). [This issue].

Mechanism of Formation of Flakes in Steel. S. S. Nosyreva. (*Stal*, 1947, **7**, 1, 49–59). The influence of hydrogen on flake formation was investigated. It is concluded that hydrogen contributes to flaking. When steel is cooled to subzero temperatures, hydrogen remains in the retained austenite. The presence of alloying elements together with hydrogen increases the austenite stability. During the decomposition of austenite, hydrogen is evolved, and since it does not dissolve in the decomposition products but accumulates in the pores, it changes into molecular form, thus creating high disruptive pressure in the voids of the metal. This pressure and the stresses set up by the decomposition of retained austenite in the pore walls cause graphite flakes to form.—V. G.

Development of Flakes in Steel. S. S. Nosyreva. (*Stal*, 1948, **8**, 8, 753–754). The influence of hydrogen on the formation of flakes in a low-alloy Cr–Ni steel was investigated. Specimens of steel were heated at 1100° C. for 10 min. and quenched in oil. Some of these were tempered at various temperatures. Specimens were saturated with hydrogen by electrolysis at room temperature. The largest number of flakes occurred in hydrogen-saturated specimens after oil-quenching and after tempering at 200° and 350° C. Their structure was mainly martensitic.—V. G.

METALLOGRAPHY

Modified Picral for Higher Alloy Steels. A. E. Nehrenberg. (*Metal Progress*, 1952, **62**, July, 91–92). It has been found that the addition of HCl to picral produces an effective etchant for 12% Cr steels. Increasing amounts of HCl decrease both etching time and contrast. Maximum contrast is generally obtained when the addition is such that an etching time of 1–3 min. is required.—B. G. B.

Thermal Etching of Iron and Steel. M. J. Olney. (*Metal Treatment and Drop Forg.*, 1952, **19**, Aug., 347–354). The author surveys literature dealing with the thermal etching of iron and steel, with special reference to the theoretical aspects. Some experimental results obtained by heating and cooling polished steel specimens *in vacuo* are described, and the nature of the bands and networks thus formed on the surface are discussed. (50 references).—P. M. C.

Micrographic Colouring Reagents for Iron and Steels. L. Beaujard. (*Rev. Mét.* 1952, **149**, July, 531–538). From a systematic study of ternary baths containing water, caustic soda, and an oxidizer, it is concluded that a composition of 40 g. NaOH, 15 g. sodium nitrate, and 60 g. water yields the best results. Examples are given of its use to reveal both physical and chemical heterogeneities in steels, including differences in orientation, segregation, and the products of the thermal decomposition of austenite.—A. G.

The Line-Broadening of Martensite in Nickel Steels. R. A. Smith. (*J. Iron Steel Inst.*, 1953, **173**, Feb., 147–152). [This issue].

Effect of Vertical Divergence on the Displacement and Breadth of X-Ray Powder Diffraction Lines. J. N. Eastabrook. (*Brit. J. Appl. Phys.*, 1952, **3**, Nov., 349–352).

Study of Alloy Structures by Photoelectronic Microradiography. J. Gumanskij. (*Hutnické Listy*, 1952, **7**, 6, 303–306). [In Czech].

Autoradiography of Steel by Means of P^{32}. N. Chvorinov, L. Jeníček, and V. Petržílka. (*Hutnické Listy*, 1952, **7**, 6, 298–302). [In Czech]. The application of the radioactive isotope of phosphorus P^{32} to study phosphorus segregation in steel castings and ingots is described. Details of the experimental method are given, and the procedure for a quantitative photometric evaluation of the phosphorus concentration from radiographs is described.—P. F.

Influence of Structure on the Grinding Spark Pattern of Unalloyed and Alloyed Steels. J. Hunger and O. Werner. (*Arch. Eisenhüttenwesen*, 1952, **23**, July–Aug., 277–286). Semi-quantitative and comparative tests have shown that the grinding spark pattern of unalloyed steels is affected not only by the carbon content but also by the microstructure. There is a surprising correlation between the distribution histogram of the size of burnt grinding dust at any particular carbon content and the histogram of ferrite or cementite grain size of the same steel. Microscopical examination of the burnt particles suggested that, in spark formation, the ferrite component of the grindings melts readily and then burns. Estimations of carbon monoxide from the sparks did not give a clear idea of the exact progress of burning of the grindings, since with increasing carbon content the quantity of gas also increased. For a given carbon content, the diameter, number, and weight of burnt particles from the spark fall within characteristic ranges. Microstructure also influenced the spark pattern of alloyed steels and cast iron and so explained the different characteristics of certain alloying elements.—J. P.

CORROSION

Radiant Heating Systems Need Cathodic Protection Too. J. F. Hirshfeld and L. P. Schaefer. (*Corrosion*, 1952, **4**, Apr., 140–142). The radiant heating installation under the concrete floors at the St. Gilbert and Coolidge bus terminals of the Detroit tramways suffered extensive corrosion due to salt and water that had melted from the underside of vehicles seeping through cracks in the floor. A cathodic protection system, using graphite rods as anodes, installed under the floor has overcome the trouble.—G. P. A.

Chlorinated Rubber Corrosion-Resistant Coatings. F. K. Shankweiler, G. N. Bruxelles, and R. E. Whitney. (*Corrosion*, 1952, **4**, Apr., 130–139). Chlorinated rubber needs modification with resins, for proper adhesion and high gloss, and with plasticizers, for flexibility and toughness, to be useful as a protective coating. Tests in salt fog (20% NaCl at 100° F.) and in tap water at 100° F. indicate very good protection with pigmented coatings based on 50–60% chlorinated rubber. The large proportions of aromatic solvents needed for chlorinated rubber limit the number of suitable primers for chlorinated rubber paints. When properly formulated with corrosion-resistant pigments, such primers, together with chlorinated rubber top-coats, give good protection.—G. P. A.

Radioisotopes in the Study of Metal Surface Reactions in Solutions. M. T. Simnad. (*Inst. Metals Monograph and Report Series*, 1952, No. 13, 23–58). Radio-isotope studies are reviewed, and generalizations are made about the mechanism of metal–ion exchange in solutions. The passivating action of chromates is studied, corroborating a film theory. The author also deals with self-diffusion and isotopic exchange in surface films and aqueous solutions. (195 references).

Rubber Anti-Corrosive Linings for Process Plant. (*Engineering*, 1952, **174**, July 11, 54). The uses of rubber anti-corrosion linings for steel and other metal vessels used in many industries are discussed. Details are given on the preparation of the parent metal, the application of the adhesive, and the inspection of the finished linings.—M. D. J. B.

Hydrogen Causes Embrittlement of Forged Compressor Blades. A. E. Durkin. (*Steel*, 1952, **130**, Mar. 24, 76–78). Corrosion of compressor blades was found to be due to hydrogen embrittlement. Tests have shown that a vinyl coating can largely eliminate this blade cracking.—A. M. F.

Influence of Oxide Layers and Chlorine Ions on the Electrochemical Behaviour of Passive Iron, Chromium, and Iron–Chromium Alloys in Dilute Nitric Acid. T. Heumann and W. Rösener. (*Z. Metallkunde*, 1952, **43**, Feb., 42–44). Oxide layers produced on an iron–chromium alloy (containing up to 20% Cr), by heating in air at 140° C., gave a polarization potential in dilute HNO_3 equal to that given by pure platinum in the same solution. The polarization curve shows the same behaviour as that of pure iron, if not taken too slowly. Above 1·4 V. the oxide skin is loosened and pushed from the surface, the latter reverting to the original state. The oxide skin is not identical with the passivating layer. It is not possible to obtain a 'break-through' potential for pure iron in the passive condition, above which, as with aluminium and chromium, only metal enters into solution but no oxygen is evolved. These results agree with the theories of U. F. Frank concerning passivating and activating of iron.—P. F.

Stress Corrosion in Chromium-Nickel Stainless Steels. C. Edeleanu. (*J. Iron Steel Inst.*, 1953, **173**, Feb., 140–146). [This issue].

Influence of Stress and Temperature in Stress-Corrosion Tests. O. Lissner. (*Z. Metallkunde*, 1952, **43**, May, 147–150). Assuming that the life of a stress-corrosion test piece is expressible as a probability function of the stress and the temperature, an attempt is made to determine the applicability of this concept to stress-corrosion data relating to unalloyed steels and to some light metal alloys. The interpretation of the formula obtained shows that the stress-life plot on a log–log scale has physical significance. The temperature dependence of the life of the test piece must, however, be represented by a plot of the logarithm of the life against the inverse of the absolute temperature.—P. F.

The Protective Action of Paints. J. E. O. Mayne. (*Research*, 1952, **5**, June, 278–283). Inhibition of corrosion may be effected by the arrest of cathodic or anodic reactions, or by inserting a high electrolytic resistance between the cathodic and anodic areas. Paint films are so permeable to water and oxygen that they cannot inhibit the cathodic reaction, and it is only when they contain certain pigments that they can suppress the anodic reaction. So, in general, paint films inhibit by virtue of their high electrolytic resistance.—J. C. B.

Swedish Experience of Ship Preservation. R. Lindh. (*Tekn. Tidskr.*, 1952, **82**, Aug. 19, 653–655). [In Swedish]. Effective protection against corrosion is afforded when relative air humidity is maintained at 30–40%. Swedish naval experience with dehumidification by adsorption units, which have an extraction capacity of 50 litres/day when the ingoing air has a relative humidity of 50–60% at +10° C., is described. Operation and installation of the units are outlined, preparatory measures such as ship drying and sealing are described, and brief details are given of tests to ascertain the efficiency of the sealing of Swedish warships.—G. G. K.

ANALYSIS

The Separation and Analysis of Metallic Carbides from Steel. R. Pemberton. (*Analyst*, 1952, **77**, June, 287–292). Anodic decomposition of the steel specimen in a citric-acid/potassium-iodide electrolyte is used to isolate the carbide phase. This is separated and analysed microchemically. Procedures are given for the determination of carbon, manganese, chromium, vanadium, molybdenum, tungsten, titanium, niobium, and iron in the residue.—T. E. D.

New Determination of Cobalt in the Presence of Iron and Chromium. F. Sierra and F. Carceles. (*Anal. Fis. Quim.*, 1951, **47B**, Dec., 811–814). [In Spanish]. The gravimetric method for determining cobalt as $[Hg(SCN)_4]Co$ is modified for cases where iron and chromium are also present.—R. A. R.

Changes in Potential of the Dropping-Mercury Electrode during Drop-Formation, and Measurement of Potential in Polarographic Analysis. W. Furness. (*Analyst*, 1952, **77**, July, 345–355). The factors that influence the value of electromotive force applied to the cell circuit were examined. A technique for measuring the potential of the dropping mercury electrode, at the instant of maximum drop size, with respect to that of a reference electrode, and to the nearest tenth of a millivolt, was developed, using the Pogendorff compensation method. Throughout the investigation, a Tinsley polarograph, model V3211, was used.—T. E. D.

Flow-Through Electrode Tubes Suitable for Use in Routine Polarographic Analysis. F. C. Spurr. (*Metallurgia*, 1952, **45**, Jan., 52–53). An account is given of a flow-through tube with a mercury pool, which was devised to overcome difficulties in changing the solutions to be analysed.—B. G. B.

XUM

Investigations on Colorimetric Methods of Metallurgical Analysis. Part IV—Estimation of Silicon in Steel Using the Duboscq Type of Colorimeter. G. V. L. N. Murty and N. C. Sen. (*Metallurgia*, 1952, **45**, Jan., 53–54). By using light filters, complementary in colour to the solutions to be analysed, the Duboscq-type colorimeter can be applied with greater accuracy. The procedure adopted for the analysis of silicon in steel is described. Results obtained by this visual method and absorptiometric and gravimetric methods are given, and it is seen that the visual method is comparable in accuracy with the others.—B. G. B.

An Automatic Colorimeter. H. Dijkstra and B. S. Sieswerda. (*Appl. Sci. Res.*, 1952, Section B, **2**, 6, 429–452). A description is given of the principles and construction of an automatic photoelectric colorimeter which may be used for continuously recording the absorption of a liquid flowing through the measuring tube. Factors influencing the theoretical accuracy and sensitivity are discussed in detail.—B. G. B.

Determination of Gases in Ferrous Metals. Iu. A. Klyachko and A. G. Atlasov. (*Zavodskaya Laboratoriya*, 1950, No. 3, 283–290). [In Russian]. A detailed account is given of the apparatus and microanalytical technique for the determination of hydrogen in ferrous metals by the vacuum-heating method in which the gas is removed at temperatures of the order of 600–700° C. Hydrogen determinations in a 1·13% carbon steel showed good agreement with results obtained by the vacuum-fusion method, and micro-analysis of the gases evolved is considered unnecessary for this type of metal. iAlthough the vacuum-heating method does not always result n the removal of all the hydrogen, it gives a reliable indication of the existence in the steel of defects associated with excess hydrogen.—S. K.

On the Direct Determination of Oxygen in Solid Fuels. H, Guérin, M. Bastick, and P. Marcel. (*Chaleur et Ind.*, 1952. **33**, June, 177–180). On the basis of a comparison of two methods for the determination of oxygen, namely high-temperature pyrolysis and hydrogenation, a procedure is suggested which is both quick and accurate for a variety of coals ; the time necessary is 30 min.—T. E. D.

A Combustion Chamber for the Semi-Micro Determination of Carbon Monoxide and Hydrogen. G. T. Rogers. (*J. Sci. Instruments*, 1952, **29**, June, 201). A simple apparatus is described for the determination of carbon monoxide and hydrogen in mixtures which do not contain hydrocarbons.

A Modified "Thermal Conductivity" Gas Analyser for Measuring Methane in Air or Carbon Dioxide. F. W. Pritchard. (*J. Sci. Instruments*, 1952, **29**, Apr., 116–117). The theory of the performance of a convective gas cell instead of a conductive cell in a standard type of conductivity gas analyser is shown, in some cases, to make the instrument insensitive to a third gas component. Details are given of the conversion of an instrument, measuring low concentrations of methane by catalytic combustion of the gas on an activated platinum wire, to the use of convective cells.—H. D. W.

Acceleration of the Filtration of Solutions Containing Silica. G. F. Proskuryakova. (*Zavodskaya Laboratoriya*, 1950, No. 3, 364–365). [In Russian]. Conditions for obtaining silica in the colloidal state are considered and applied to filtration in the analysis of cast iron and other ferrous materials.—S. K.

Determination of Free and Combined Carbon in Steels. N. M. Popova and M. F. Rybina. (*Zavodskaya Laboratoriya*, 1950, No. 3, 280–283). [In Russian]. In the method described for determining free and combined carbon in steels not containing chemically stable carbides, 50–100-mg. samples of carbide residues obtained by anodic solution from several homogeneous samples are used. The method is based on the decomposition by HCl of the carbide suspension in glycerine by adding the suspension drop-wise to the boiling acid of 1·13–1·15 sp. gr. The constancy of the composition of iron carbide in carbon steels with 0·73–1·34% carbon at 600°, 500°, 400°, 300°, and 200° C. or annealed at 600°, 700°, and 800° C. was confirmed, making it possible to determine combined carbon in such steels from the content of iron combined as carbide.—S. K.

Colorimetric Determination of Small Quantities of Aluminium in Steels, Metallic Chromium, and Cobalt. F. M. Shemyakin and S. I. Barskaya. (*Zavodskaya Laboratoriya*, 1950, No. 3, 278–283). [In Russian]. A new method is described for the colorimetric determination of 0·1 to 0·01% aluminium, using a new blue dye reagent in the presence of sulphuric acid. Chromium, nickel, manganese, magnesium, copper, and ferrous iron do not interfere with the determination, the colour of the dye does not change with time, and the amount used is negligible.—S. K.

Use of Iodic Acid Salts in Volumetric Analysis. V. S. Syrokomskii and S. I. Melamed. (*Zavodskaya Laboratoriya*, 1950, No. 3, 273–277). [In Russian]. The preparation of standard solutions of periodate and their use for the volumetric determination of reducing agents is described. Details are given of the satisfactory results obtained using periodate with diphenylamine, diphenylamine sulphate, or phenylanthranilic acid, as indicator for the determination of iron in ores or pure salts.—S. K.

Mercuro-Metric Ferrous Iron Determination. A. S. Vetrov. (*Zavodskaya Laboratoriya*, 1950, No. 3, 362). [In Russian]. The method of ferrous iron determination described is based on oxidation by the chlorate iron, followed by the titration of the resulting chloride with mercurous nitrate, using diphenylcarbazone in alcohol as indicator.—S. K.

Simplified Method of Determining Ash in Coal. M. M. Lifshits. (*Zavodskaya Laboratoriya*, 1950, No. 3, 263–266). [In Russian]. For the determination of ash and moisture in coal it is proposed to use separate samples of < 1-mm. particles without grinding. Satisfactory agreement under laboratory conditions of these results with those obtained by the standard method is claimed.—S. K.

Rapid Determination of Phosphorus in Iron Ore Agglomerate. R. I. Kanevskaya. (*Zavodskaya Laboratoriya*, 1950, No. 3, 356–357). [In Russian]. In the method described, which is suitable for iron ore agglomerates without appreciable titanium, arsenic, or vanadium, the acid-insoluble residue is directly fused with soda. The melt is treated with dilute HCl, and then carefully neutralized with ammonia. After boiling, the precipitate is filtered off and the phosphorus removed by washing with warm HNO_3, the solution obtained being combined with the original acid solution of the sample. The method was tested with standard samples of ore and gave satisfactory results.—S. K.

Rapid Photoelectric Method of Determining Small Quantities of Vanadium in Iron Ores. N. S. Tkachenko and R. M. Petrunina. (*Zavodskaya Laboratoriya*, 1950, No. 3, 357). [In Russian]. Modifications of a photoelectric method for determining vanadium in iron ores are briefly described ; these have reduced the time for a determination from 40 to 15 min.

The Rapid Determination of Copper in an Aluminothermic Ferrotitanium. L. Bonnafous. (*Chim. Analy.*, 1952, **34**, Aug., 176). The method, applicable to copper contents of 0–2%, is accurate and rapid. The copper in the alloy is separated as a froth during solution in H_2SO_4. This is separated by filtration and the copper is determined electrolytically.—T. E. D.

Determination of Silica in Ferrosilicon and Other Steelworks Raw Materials by Titration. B. Kysil. (*Hutnik* (Prague), 1952, **2**, 7–8, 180–182). [In Czech]. Silica, converted into silicic acid, is titrated with sodium hydroxide. Details of the procedure and precautions involved in obtaining the silicic acid are given.—P. F.

Iodometric Codetermination of Copper and Iron. R. C. Brasted. (*Analy. Chem.*, 1952, **24**, June, 1040–1041). The method developed allows the determination of copper and iron in aliquot portions of the same solution. Copper can be determined in the nitric acid solution when sulphamic acid is present; potassium acid phthalate and ammonium acid fluoride are used in equal quantities as complexing agent for the iron present.—T. E. D.

Measurement of Oxygen Concentration in Gases. A. Linford. (*Coke Gas*, 1952, **14**, June, 195–200). There are innumerable uses for oxygen analysers in all branches of industry. Until recently, chemical absorption methods were used, but these have now been superseded by systems based on the unique magnetic property of oxygen. Oxygen and nitric oxide are the only known paramagnetic gases, and oxygen is very much more paramagnetic than nitric oxide. There are two main methods: (1) The measurement of the force resulting from the presence of the gas in a magnetic field; and (2) the magnetic wind method. These are described with the aid of diagrams, and, finally, carrier gas effects are discussed.—T. E. D.

Determination of Nitrogen in Steel. R. H. A. Crawley. (*Anal. Chim. Acta*, 1952, **7**, July, 63–67). [In English]. The accuracy of the chemical method is discussed, and the impor-

tance of the complete conversion of nitrides to ammonia is emphasized. A method is proposed for the accurate determination of ammonia, in which Nessler's reagent is used, and the colour is measured by absorptiometer.—T. E. D.

HISTORICAL

The History of the Wood Screw and the Development of the Usco Plant. (*Wire Ind.*, 1952, **19,** Sept., 847, 849). The history of the Screw Division of Guest, Keen and Nettlefolds, Ltd., which began in 1823, is summarized, and brief particulars of a new screw plant of the United Steel Company of South Africa are given.—R. A. R.

Australia in Relation to the Iron and Steel Industry. R. H. M. Rowe. (Australian Inst. Metals : *Australasian Eng.*, 1952, May 7, 50–54). The early history and development of the iron and steel industry in Australia is briefly outlined. Raw material sources are discussed, and all the steel and associated works in Australia are listed together with brief details of their main products and activities.—P. M. C.

An Old Derbyshire Tramroad, Wagon, and Rails. (*Edgar Allen News*, 1952, **31,** July, 187). The last remnants of the Peak Forest Tramroad, to be seen at Buxworth, are described. The tramroad operated from 1800 for over 120 years, linking limestone quarries at Doveholes with wharves of the Peak Forest Canal at Buxworth.—D. L. C. P.

The Earl of Dudley's Level New Furnaces. T. M. Hoskison. (*Newcomen Society Advance Copy*, Nov., 1952). An historical account is given of the changes in the blast-furnace plant, from 1806 to the present time, at what is now the Round Oak Steel Works at Brierley Hill.—R. A. R.

The King's Ironworks in the Forest of Dean, 1612–1674. H. R. Schubert. (*J. Iron Steel Inst.*, 1953, **173,** Feb., 153–162). [This issue].

The German Iron Mining Industry, Early History and Development. A. E. Lance. (*Mine Quarry Eng.*, 1952, **18,** July, 223–226). The author traces the location, nature, techniques, manning, and output of German iron ore mines from earliest evidence to modern times.—D. L. C. P.

MISCELLANEOUS

The Application of Science to Industry. F. W. G. White. (*Australasian Eng.*, 1952, June 7, 48–53). The author outlines the aims of applied and co-operative research, and assesses Australia's research resources. He contends that there is, in Australia, too great a tendency for industry to leave research to the State.—P. M. C.

Research Organisation. R. J. Hopkins. (*Proc. Australasian Inst. Min. Met.*, 1950, Sept.–Dec., 277–294). The author discusses the aims of research and its organization in the industrial field, under the headings of definition, pure research, industrial research, research functions, research teams, and organization. Finally, a description is given of the projects, and accommodation and staffing of the Research Dept. of the Broken Hill Associated Smelters Pty., Ltd., Port Pirie, Australia.—D. L. C. P.

The Swinden Laboratories, Rotherham. (*Engineer*, 1952, **194,** Aug. 1, 166–168 ; *Engineering*, 1952, **174,** Aug. 1, 150–151 ; *British Steelmaker*, 1952, **18,** Aug., 398–401 ; *Met. Indust.*, 1952, **81,** Aug. 15, 131–133 ; *Refractories J.*, 1952, **28,** Aug., 367–376 ; *Metallurgia*, 1952, **46,** Aug., 89–93). Illustrated descriptions are given of the new research laboratories of the United Steel Companies, Swinden House, Rotherham.—R.A.R.

Standardization of Radioactive Isotopes by Coincidence and γ-Ray Ionization. W. E. Perry. (*N.P.L. Symposium on Recent Developments and Techniques in the Maintenance of Standards*, May, 1951, 45–50 : H.M. Stationery Office, 1952). The results of measurements of specimens of Co^{60} and Na^{24} by these two methods are given. Owing to incomplete knowledge of the numerical values of the factors relating ionization to energy, the uncertainty in the ionization values is about $\pm 4\%$, and the differences between the ionization and coincidence values do not exceed these limits.—B. G. B.

The Industrial Uses of Radioactive Materials. K. Fearnside. (*Chem. Ind.*, 1952, Sept. 20, 920–922). Radioactive isotopes, chemically identical with natural elements, but distinguishable by characteristic energy radiations, are used mainly to trace the behaviour of large quantities of inactive material in industrial reactions, *e.g.*, phosphorus in steelmaking, chromium in plating baths, or as a means of instrumental control of the operation of a particular process, *e.g.* sheet rolling, packaging, and fire prevention. With adequate precautions, hazards to health are practically non-existent.

The Maintenance of Radioactive Standards with the 4π Proportional Counter. R. C. Hawkings, W. F. Merritt, and J. H. Craven. (*N.P.L. Symposium on Recent Developments and Techniques in the Maintenance of Standards*, May, 1951, 35–45 : H.M. Stationery Office, 1952). The 4π counter is shown to be ideally suitable for overcoming many of the problems of absolute beta counting. The counter described is extremely rugged and can be dismantled, decontaminated with detergents, and reassembled ready to count in about 10 min.—B. G. B.

A Fast Scanning Mechanism for Use with a Geiger Counter X-Ray Spectrometer. J. Adams. (*J. Sci. Instruments*, 1952, **29,** Oct., 324–325).

Time and Motion Study. C. D. Hunter. (*Foundry Trade J.*, 1952, **93,** Aug. 28, 233–237). This paper deals with the way in which proper times for operations are established, with particular reference to the Mueller method, and to the Yale–Towne ' 100% allowed-hour ' incentive plan.—E. T. L.

Some Aspects of Cost Accounting in the Steel Industry. H. J. Tapner. (Australian Inst. Metals : *Australasian Eng.*, 1952, May 7, 72*a*–72*g*). The author discusses the purposes and functions of cost accounting and follows with a general description of methods employed. Labour segregation and the allocation of material and overhead expenses are dealt with, and the use of cost information relative to policy formulation and plant operation is discussed. (9 references).

BOOK NOTICES

CLAUSER, H. R. " *Practical Radiography for Industry.*" 8vo, pp. x + 301. Illustrated. New York, 1952 : Reinhold Publishing Corporation. (Price 60*s.*)

The purpose of this book is to present, in a concise form, practical information and data on the use of radiography in industry. There are comparatively few books available on this rapidly developing subject, and the publication of a new work is therefore an event of some importance. Although laying stress on the practical aspects, the author does not shirk the fundamentals of the subject, and these, together with general descriptions of radiographic procedures, films, film processing, etc., occupy seven of the 14 chapters. A further two chapters deal in some detail with the radiography of welds and castings by medium voltage X-ray techniques. The rest of the book is devoted to gamma-ray radiography, fluoroscopic methods, high-voltage radiography, miscellaneous applications, and radiation protection.

As is to be expected, the data on X-ray equipment, films, screens, and developers, are confined to American products, and it follows that this important aspect of the book is of little value to workers on this side of the Atlantic. This is a matter for regret, as it was clearly intended to present sufficient information for even a beginner to embark on the simpler forms of radiography with reasonable hopes of immediate success.

With regard to the general contents, many aspects of the subject are up-to-date and in this respect reference should be made to the chapter on high-voltage radiography, in which multi-million voltage equipment and techniques are discussed, and to the sections on xeroradiography, microradiography, and spot-weld radiography. On the other hand, the chapters on gamma-ray radiography and protection are not as up-to-date as is to be desired. In the former, for example, there is little information regarding artificially radio-active materials, it being obvious, both here and elsewhere in the book, that gamma-ray radiography is considered largely in terms of radium. It is true that cobalt^{60} receives some treatment, but iridium^{192} is dismissed in a single sentence and is not indexed, no other artificial material being mentioned at all. Furthermore, in referring to quantities of cobalt^{60}, use is made of the obsolete expression ' milligrams radium equivalent,' there being no reference to the curie in this connection. The curie is mentioned elsewhere, however, and on p. 149 we find the surprising statement that ' A millicurie is the intensity of

gamma-ray radiation emitted by a milligram of radium.' Two other ways of defining the curie are also given in this section, but the current definition (1950), which is in terms of disintegration rate, is ignored. In the chapter on radiation protection, the author quite rightly stresses the need for strict protective measures and quotes extensively from the 'Safety Code for the Industrial Uses of X-Rays' published by the American Standards Association in 1946. He states (p. 286) that "The universally accepted standard is a permissible daily dose of 0·1 roentgens," and then infers that protection should ensure that, in occupied space, the dose should not exceed 0·1 r. during any 24-hr. period. The tables and data of the Safety Code are based on a dose of 0·1 r. per working day of 8 hr., *i.e.*, 12·5 milliröntgens/hr., and there is thus an inconsistency here. This is of less importance, however, than the fact that since the publication of the Safety Code there has been a revision of the maximum permissible dose, and it is now fixed at half the previous value. All the numerical data presented in this chapter need adjustment in the light of this fact.

Apart from the matters referred to above, the book contains a large number of errors, some trivial and others more serious. There is no point in detailing these here, but, by way of illustration, attention is drawn to two widely differing examples. The first concerns Fig. 1–1, p. 3, which depicts the basic principles of radiography, namely, a diverging beam, a non-uniform specimen, and a film. The paths of the rays and the blackenings corresponding to various specimen thicknesses are indicated. Unfortunately, the variations in blackening are shown as corresponding to the actual positions of the irregularities in the specimen and not to their projected positions resulting from the divergence of the beam. This cannot but confuse the reader for whom the associated elementary description is intended. The second example is taken from pp. 108, 109, where characteristic curves of films are being discussed. Here the mistake is made of referring to density changes in terms of percentages, and one of the erroneous conclusions drawn is that, if the characteristic curve has unit slope, doubling exposure will cause the density to be doubled also.

It will be concluded from the foregoing that neither from the practical nor from the general point of view has the book much to offer the industrial radiologist in Britain.

E. E. SMITH

HUME-ROTHERY, W., J. W. CHRISTIAN, and W. B. PEARSON. "*Metallurgical Equilibrium Diagrams.*" (Physics in Industry.) La. 8vo, pp. 311. Illustrated. London, 1952 : The Institute of Physics. (Price 50*s.*)

This book is intended primarily for fourth-year Honours students and research students in metallurgy, and for this purpose it is a very good book indeed, giving them an ample sense of the difficulties and pitfalls of the work, good advice on the way to set about it, and a high standard of performance at which to aim.

It is a book that can be read with pleasure. The authors allow their own experiences and preferences to appear. Occasionally there are echoes of old controversies, and now and again a hobby-horse is trotted forth, but on the whole the judgments are firm and fair. The book starts with an admirably concise summary of the general theory of binary systems. An account of experimental methods follows, including a summary of methods of pyrometry, after which the determination of the liquidus, of the solidus, and of phase boundaries in the solid state are dealt with in detail, separately. Finally, there is a treatment of ternary equilibria, not exhaustive, but with a helpful selection of examples, and a chapter on the presentation of results, which is largely a plea to authors and learned societies not to sacrifice essential detail in the interests of brevity.

The necessary distinction is drawn throughout between methods suitable for temperatures below 1100° C. and those for temperatures between 1100° C. and 1600° C., and above 1600° C. The authors speak most authoritatively of the lower range of temperatures. When dealing with the higher ranges, the book tends to become a compilation of extracts from the literature, but the difficulties of work at high temperatures and the necessity of maintaining the closest watch over changes in the chemical composition of the sample are suitably emphasized.

The authors rely principally on a combination of thermal curves, microscopic examination, and X-ray methods, and there are few problems that will not yield to a sufficiently skilled application of these three tools. They, perhaps, do less than justice to the possibilities of dilatometric, electrical-resistivity, and magnetic methods, each of which can yield most elegant results in the hands of a master. There is little reference in the book to the help that can be obtained from the judicious use of hardness tests, nor to the, perhaps too fashionable, use of measurements of elastic constants and damping capacity. The reviewer looked in vain for the authors' assessment of the place of radioactive tracers in the determination of equilibrium diagrams.

There are a few general criticisms. The book is written too much as if the determination of equilibrium diagrams were an end in itself, and, since most of the students will ultimately employ their skill in the metallurgical industries, it would have been better to generate the opposite impression. Too little is said about unstable and transitional constituents and the complications to which they can give rise. A chapter on the mechanism of transformation would not have been out of place. Too little is said about the influence of impurities and about the special methods for studying the constitutional effects of minor constituents. Though high purity is desirable, it is not always possible to achieve it, and the student must know how not to be misled. When he goes out into industry he will find himself more often studying the effect of a small addition to an alloy whose constitution is well known, than studying a complete and unknown system. There is a curious over-estimate throughout the book of the accuracy that is normally achieved in chemical analysis. The cases in which an alloy can be analysed with such accuracy that the total will fall between 99·95% and 100·03% are few, as the minutes of any committee dealing with standard methods of analysis will show. Nevertheless, the insistence on continual analytical control is entirely good. In too many papers the analyst's contribution to the work is overlooked, and in too many papers the word 'pure' should be crossed out and the words 'not analysed' be substituted.—N. P. ALLEN

"*International Tables for X-Ray Crystallography.*" Volume I. "*Symmetry Groups.*" Editors, N. F. M. Henry and K. Lonsdale. Historical Introduction by M. von Laue. Published for the International Union of Crystallography, 4to, pp. xii + 558. Illustrated. Birmingham [1952] : Kynoch Press. (Price 105*s.*)

This book supersedes the "International Tables for the Determination of Crystal-Structures," published in 1935, but has been revised and amplified with new material to such an extent that it should be considered largely as a new work. Its chief purpose is to provide the fundamental data necessary to those engaged in structure analysis, to whom it will indeed be indispensable, but the advanced student, once having comprehended the basic knowledge from more elementary textbooks, could hardly do better than consolidate it from, at least, the introductory sections.

The work is of such excellence that it can be recommended in its entirety. It has been prepared, with the support of U.N.E.S.C.O., under the auspices of the International Union of Crystallography, by a Committee, with Professor Kathleen Lonsdale and Dr. N. F. M. Henry as Chief Editors, and numerous experts from various countries have contributed. In contrast to the earlier three-language form, English is here used exclusively, with, however, the addition of a crystallographic dictionary in English, French, German, Russian, and Spanish. This is considered fully adequate, though, of course, national committees may well advocate translations in individual countries.

After an historical introduction by M. von Laue, which in itself is a small masterpiece in tracing the development of a science (from Kepler's almost apologetic pamphlet on snow-crystals, to the Braggs' and von Laue's thriving offspring of the present day), there follow five chapters of very unequal length, dealing with Crystal Lattices, Point-Group Symmetry, Space-Group Symmetry, 'Special Topics,' and an Index of Space-Group Symbols. The presentation, although, of course, rigidly mathematical, is lucid, and builds up the fundamental framework of Crystallography as a systematic whole. The layout of the comprehensive tables, which naturally occupy most of the book, is excellent, and certainly an improvement upon the previous edition. Some new features are the presentation of two-dimensional

space-groups and point-groups, in addition to the three-dimensional ones, useful in dealing with planar projections in structure analysis, of Patterson-Harker functions, of Wilson's statistical approach to intensity distributions, and of other important developments of recent years. The 'Notes on Special Topics' are reserved for less essential subjects, some of which previously occupied undue space, and, based on users' opinions, several omissions have rightly been made, such as cubic diagrams, with a view to a possible future supplement if desired.

The 14 Bravais lattices and the concept of the reciprocal lattice are introduced in Chapter 2, while the 32 Point-groups and 230 space-groups, in addition to the planar ones, are then beautifully laid out, reflecting the labour and care which have gone into their compilation.

The treatment is methodical throughout, but never so detached as to loose sight of practical usefulness; 'convention' is clearly distinguished from points of first principle, and allowance is made for unit cell and other types of transformation, and tabulated cross-references to symbols, which will prove convenient.

The comprehensive tables of structure factors and electron-densities for the two- and three-dimensional space-groups required in Fourier analysis are given, and their use is fully explained, with several examples. The recent work, for instance, by Ito, on transformations permitting (in principle) a universal method of indexing powder-photographs is included under 'Special Topics,' as well as sub- and super-groups of space-groups.

As far as readers of this *Journal* are concerned, the work is clearly valuable in any laboratory dealing with crystal-structure determinations, for instance, on metallic and mineralogical phases. Two further volumes, giving mathematical, physical, and chemical tables, are to follow.

It has been said in recent years by unbiased observers, that crystallography may serve as a 'model science' in its systematic build-up and in its practical organization, a conception which is again underlined by the work under review.—H. J. GOLDSCHMIDT

O. H. LEHMANN. "*Radreifen, Radscheiben und Vollräder.*" 8vo., pp. 91. Illustrated. Düsseldorf, 1952: Verlag Stahleisen m.b.H., (Price DM 14.50)

The manufacture of tyres, discs, and solid wheels is only a comparatively small part of the field of hot-working, and the literature dealing with this field is correspondingly small. The author feels that this is not merited, since everything that moves on rails needs tyres, discs, or solid wheels. Even up to the first decade of the present century, departments manufacturing these products generally represented only a part of the output of forging works, and it was only later that they became specialized.

The opening chapters review the history of the development of the manufacture of tyres, discs, and solid wheels, and the materials used in each.

The main body of the work describes in detail the types of ingot (including the pear-shaped small ingots used for making single tyres), the various processes of parting the ingot into cheeses, methods of rolling and forging tyres, wheel discs, and solid wheels, types of reheating furnaces, and finishing processes (including dishing and checking for ovality). The last portion of the book covers heat-treatment equipment and testing.

Some notes are included on the special Munton process of tyre production in which rings or hollow ingots were cast centrifugally. The idea was that the material should be consolidated right from the beginning. The hollow ingot was cut and the rings were pre-rolled and finish-rolled in a separate mill. Munton's original idea has been used many times in various attempts to develop centrifugal casting methods.

This work is a handy description of the processes in tyre, disc, and solid wheel production in logical sequence, and in one comparatively small book. It does not theorize, and most of what it contains will not be unfamiliar to the manufacturers of these products.

A useful classified bibliography including French, Luxembourg, Russian, and Spanish references, in addition to German, British, and American, is included.—R. SEWELL

MEETHAM, A. R. "*Atmospheric Pollution, Its Origins and Prevention.*" 8vo, pp. viii + 268. Illustrated. London, 1952: Pergamon Press, Ltd. (Price 35*s.*)

The author considers the study of atmospheric pollution an untidy science and it is all the more praiseworthy that he has succeeded in presenting a book which is, from its various aspects, pleasant to read.

True enough, those who are concerned with atmospheric pollution from all angles may consider that the book has too strong a bias towards the particular side resulting from the combustion of fuel. Equally, the extent to which the subject of combustion is treated, in particular that related to industrial usage, may be considered excessive, especially in view of the results already achieved by the campaign of the Ministry of Fuel and Power and the efforts of industry in general towards the more efficient use of fuel. The text of this part also suffers from those slight inaccuracies often met when an author covers a wide field not entirely his own.

In the second part of the book, however, the author is fully at home, and his expert knowledge is amply in evidence. The basic data he gives, the description of the methods of assessment of atmospheric pollution, its distribution and changes, should all be of great value to those whose duty it is to try to eliminate or combat this evil.

Although the book does not refer at length to the share that the iron and steel industry may still have in polluting the atmosphere, it is hoped that its contents may help to make those concerned realize that there is no room for complacency on the subject.—NEIL H. TURNER

WULFF, JOHN, HOWARD F. TAYLOR, and AMOS J. SHALER. "*Metallurgy for Engineers—Casting, Welding, and Working.*" Illustrations by George E. Schmidt, jun., 8vo, pp. viii + 624. Illustrated. New York, 1952: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd. (Price 54*s.*)

The engineering field is undoubtedly one of the most profitable for metallurgical writers and publishers because there are so many potential readers. This fact is reflected in the variety of books on engineering metallurgy that are available. Any new efforts warrant, therefore, careful attention to find out whether they cater more successfully for the best customer in a general way, or cover a neglected aspect.

First, let it be said that the present book is clearly and well written, and there is no 'hide-bound' approach. The authors are, respectively, Professor and Assistant Professor of Metallurgy at the Massachusetts Institute of Technology. The treatment is based on the curriculum for engineering students at this institute. All the clear illustrations are line drawings and appear to have been drawn specially, with some efforts at animation. The production is excellent, giving a very attractive volume on paper of good quality.

Now to consider the scope: the subtitle reads, 'Casting, Welding and Working.' The stated object has been to give an adequate understanding of metals so that they can be intelligently selected and used; and, further, "only those principles are included that are required for understanding the processing of metals into useful articles" by the processes mentioned in the subtitle. This latter statement clearly indicates restriction on the treatment of the service aspect, and this is indeed the case. The writers make clear also that the book is not intended as a source of data.

The general principles occupy approximately the first half of the book, and include smoothly written, but sometimes light, outlines of subjects such as crystallization, alloy metallurgy, deformation, mechanical testing, electrical and magnetic properties, and corrosion. The treatment of equilibrium diagrams and fundamentals of alloys reads well and may well be suitable for the authors' students, but the reviewer doubts whether it is the best form of presentation for most of the engineering students whom he has encountered. There is also doubt as to whether other aspects are not skimmed a little too lightly to be of serious value to the student. In fairness, it should be admitted that such considerations are always difficult to judge, and in any case references for further reading are provided. The accounts of the shaping processes are good and cover, in addition to those already mentioned, brazing and soldering, powder metallurgy, and metal cutting.

It will be seen that the book is primarily of interest to engineers concerned with fabrication. For engineers generally, the treatment of the factors causing deterioration in

service is inadequate, and for this reason the reviewer cannot recommend the book for engineering students, unless supplemented. However, provided the scope is understood, an interesting introduction to metallurgical principles can be obtained and a sound appreciation of many fabrication processes. The authors have certainly fulfilled their objects, and no other book comes to mind, covering a similar field so well for engineers. The book is also well worth reading by first-year metallurgical students, and it *is* a readable book.—A. R. BAILEY

NEW PUBLICATIONS

AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS. "*Electric Furnace Steel Conference, Proceedings.*" Volume 9, Pittsburgh Meeting, December 6–8, 1951. 8vo, pp. 301. Illustrated. New York, 1952 : The Institute.

AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS. "*Tube-Producing Practice.*" Institute of Metals Division Symposium Series, Volume 4. 8vo, pp. vii + 107. Illustrated. New York, 1952 : The Institute. (Price $3.00)

AMERICAN IRON AND STEEL INSTITUTE. "*Steel Products Manual.*" 8vo, Section 2. "*Semifinished Carbon Steel Products for Forging.*" Revised, pp. 47. Section 4. "*Carbon Steel Structural Sections and Sheet Steel Piling.*" Revised, pp. 76. Illustrated. Section 6. "*Carbon Steel Plates and Rolled Floor Plates.*" Revised, pp. 73. Section 7. "*Alloy Steel Plates.*" Revised, pp. 62. Illustrated. Section 8. "*Hot-Rolled Carbon Steel Bars.*" Revised, pp. 75. Illustrated. Section 9. "*Cold Finished Carbon Steel Bars.*" Revised, pp. 78. Section 16. "*Carbon Steel Wire.*" Revised, pp. 203. Illustrated. New York, 1952 : The Institute.

AMERICAN SOCIETY FOR METALS. "*Proceedings of the First World Metallurgical Congress, Oct.* 13–19, 1951." William Marsh Baldwin, jun., Editor. 8vo, pp. [xv +] 835. Illustrated. Cleveland, Ohio, 1952 : The Society. (Price 76*s.* 9*d.*)

ANGLO-AMERICAN COUNCIL ON PRODUCTIVITY. "*Training of Operatives.*" Report of one of four Specialist Teams which visited the United States of America in 1951 to study problems of training for industry. La. 4to, pp. xii + 52. Illustrated. London, 1951 : The Council. (Price 3*s.*)

ANGLO-AMERICAN COUNCIL ON PRODUCTIVITY. "*Training of Supervisors.*" Report of a visit to the U.S.A. in 1951 of a Specialist Team to study Supervisor Training and Selection. La. 4to, pp. viii + 56. London, 1951 : The Council. (Price 2*s.* 6*d.*)

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BRITISH STANDARDS INSTITUTION. B.S. 1121 : 1952, Part 28. "*Methods for the Analysis of Iron and Steel.*" Part 28 : "*Graphitic and Combined Carbon in Pig and Cast Iron.*" 8vo, pp. 7. London, 1952 : The Institution. (Price 2*s.*)

BRITISH STANDARDS INSTITUTION. B.S. 1391 : 1952. "*Performance Tests for Protective Schemes, Used in the Protection of Light-Gauge Steel and Wrought Iron against Corrosion.*" 8vo, pp. 27. Illustrated. London, 1952 : The Institution. (Price 5*s.*)

"*The Year-Book of the Coke Oven Managers' Association,* 1952." 8vo, pp. [v +] 359 + xl. Illustrated. London. 1952 : Benn Brothers, Ltd.

DALLA VALLE, J. M. "*Exhaust Hoods.*" 2nd Edition. Pp. vi + 146. Illustrated. New York, 1952 : The Industrial Press. (Price $3.50)

"*Druck-, Zug- und Mengenmessung.*" (Wärmetechnische Lehrblätter, Teil 5. Herausgegeben von der Energie- und Betriebswirtschaftsstelle des Vereins Deutscher Eisenhüttenleute (Wärmestelle Düsseldorf).) 8vo, pp. vi + 155. Illustrated. Düsseldorf, 1952 : Verlag Stahleisen m.b.H. (Price DM 8.50)

FEDERATION OF BRITISH INDUSTRIES. "*Training in Britain of Engineers from Latin America.*" Report of the British Engineering Training Mission to Latin America, May to July 1952. 8vo, pp. xiv + 64. London [1952] : The Federation. (Price 7*s.* 6*d.*)

FRIER, W. T. "*Elementary Metallurgy.*" Second Edition. 8vo, pp. x + 258. Illustrated. New York, 1952 : McGraw-Hill Book Co., Inc. (Price $4.50) ; London : McGraw-Hill Publishing Co., Ltd. (Price 38*s.* 6*d.*)

INSTITUTION OF METALLURGISTS. "*The Joining of Metals.*" Lectures delivered at the Institution's Refresher Course, 1951. 8vo, pp. 174. Illustrated. London, 1952 : The Institution. (Price 14*s.* ; Members' rate 7*s.* 6*d.*)

IRON AND STEEL INSTITUTE. "*Corrosion of Buried Metals.*" A Report of the British Iron and Steel Research Association. (The Iron and Steel Institute Special Report No. 45) 8vo, pp. x + 153. Illustrated. London, 1952 : The Iron and Steel Institute. (Price 15*s.*)

IRON AND STEEL INSTITUTE. "*Spectrographic Analysis of Low-Alloy Steels.*" A report of The British Iron and Steel Research Association. (The Iron and Steel Institute Special Report Series, No. 47). 8vo, pp. 83. Illustrated. London, 1952 : The Institute. (Price 15*s.*; Members' rate, 7*s.* 6*d.*)

JACQUET, A. "*Aciers, fers, fontes.*" T.1. (Bibliothèque de l'Enseignement technique). 4e éd. 8vo, pp. 204. Illustrated. Paris, 1952 : Dunod. (Price 480 fr.)

KOLTHOFF, I. M., and J. J. LINGANE. "*Polarography.*" Second, revised edition in two volumes. 8vo,; Vol. I pp. 436 ; Vol. II, pp. 566. Illustrated. New York and London, 1952 : Interscience Publishers Inc. (Price : Vol. I, $9.00 (72*s.*) ; Vol. II, $11.00 (88*s.*))

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